On-ground techniques for protecting local ecosystems

A best practice guide for natural landscape restoration projects along the Capricorn and Curtis coasts, including Rockhampton, Yeppoon and Gladstone.

Australian Government | National Landcare Programme

fba FITZROY BASIN ASSOCIATION

Acknowledgements

Written by Karl French, Consultant, on behalf of Fitzroy Basin Association.

Funded by the Australian Government's National Landcare Programme.

Liability Statement

This document is intended to be a guide to the current methods and techniques used for revegetation, weed control and habitat restoration projects in the Fitzroy Basin Association area. In many instances specific techniques have not been documented for the region in the past and this publication aims to address this shortfall. The Fitzroy Basin region is so large it has been impossible to address all land types and ecosystems in this current guide and, as such, it has been designed as a working document that will evolve and grow as new techniques are trialled and outcomes noted. New techniques and different habitats will be included as resources permit.

While all reasonable care has been taken in preparing this publication to ensure accuracy, the authors accept no liability arising from decisions or actions taken as a result of any data, information, statement or advice contained in this report. While all reasonable care has been taken to ensure the information contained herein is accurate, no warranty is given that the information is free from error or omission. Before taking any action or decision based on the information in this publication, readers should seek professional, scientific and technical advice.

Contents

Background

The Fitzroy Basin

The Fitzroy Basin region covers some 156,000 square kilometres of Central Queensland. It is the largest river basin flowing into the Great Barrier Reef lagoon and consists of a massive network of rivers and streams: more than 20,000 km of waterways. Some of the region's major rivers are the Connors, Isaac, Nogoa, Mackenzie, Dawson and Fitzroy rivers.

Population and land use

Around 230,000 people live and work in the communities of the Fitzroy Basin. The region is quite sparsely populated with urbanisation centred on the cities and towns of Rockhampton, Yeppoon, Emerald and Gladstone. Current land use across the basin is 86 per cent grazing; 7 per cent cropping; 6 per cent natural land uses; 5 per cent forestry; and 1 per cent urban, mining and feedlots. Proximity to the southern Great Barrier Reef makes the region's coastal townships of Yeppoon, Emu Park, Boyne Island and Tannum Sands popular destinations for recreation and local tourism.

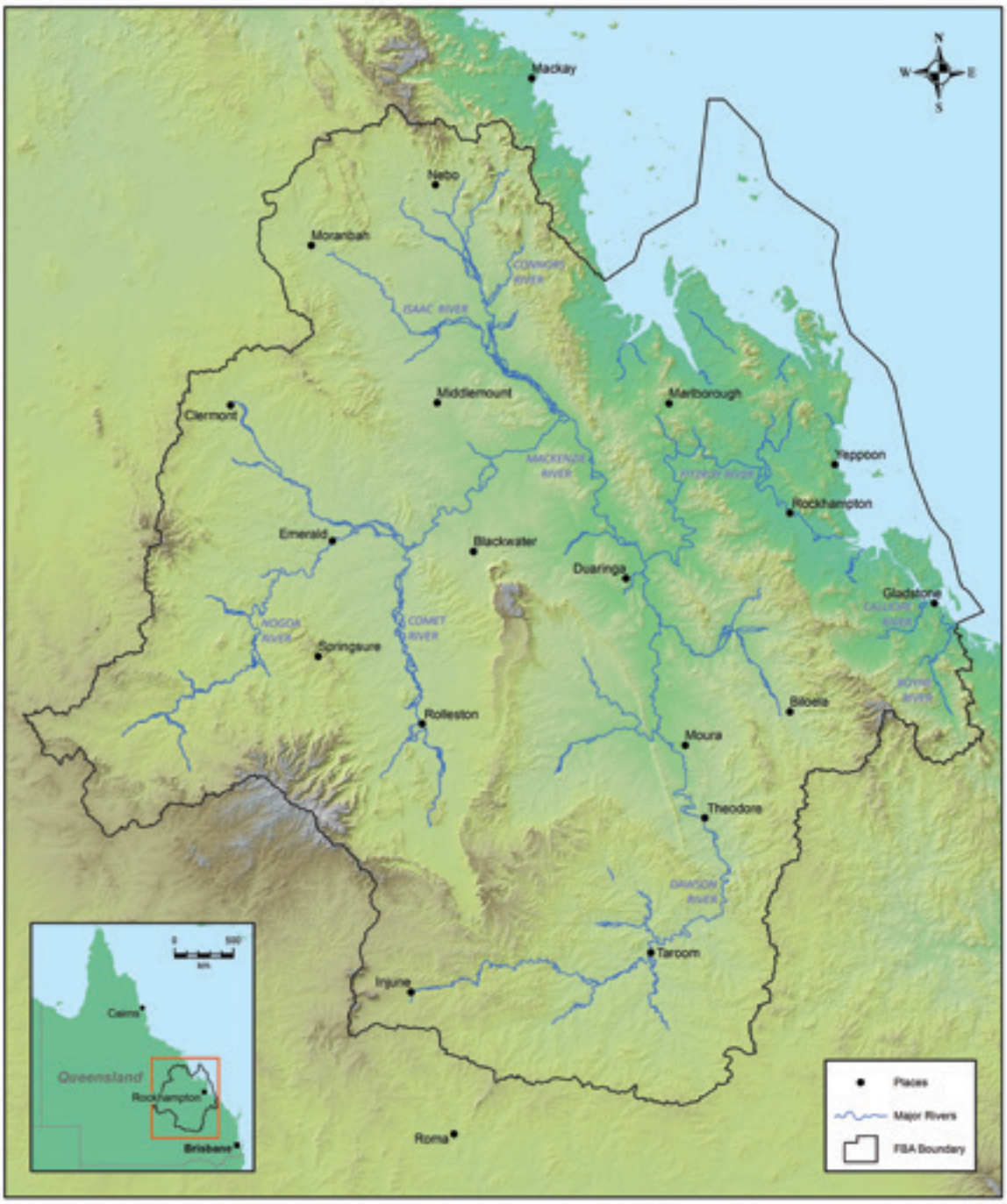
Climate

The region is characterised by a sub-tropical to semi-arid climate with highly variable rainfall. Rainfall tends to be concentrated in the summer months between December and February, and is higher in the sub-tropical coastal areas (averaging 1,000 mm per annum) and dwindling to around 500 mm per annum in the semi-arid interior. Summer temperatures average in the mid-30 degrees Celsius, whereas they fall to single figures in inland areas during winter. Frosts are not uncommon away from the coast, which tends not to suffer the extremes of the inland. Drought is common across the region and rainfall is often concentrated into severe tropical storms and flooding rains.

Impacts on the environment

Historically, much of the region was covered in Brigalow scrub, which was extensively cleared from the 1960s onwards. Consequently, land owners face challenges to maintain sufficient ground cover to prevent erosion during heavy rainfall events following periods of prolonged drought. Ongoing land and water quality impacts from the mining, grazing and broadacre cropping industry, in particular in terms of run-off, sediment loads and nutrient enrichment, are of concern due to the proximity to the Great Barrier Reef. Urban development of coastal regions has impacted local ecosystems through loss of natural stream flows, increased urban wastewater flows, removal of native buffer vegetation and increasing contaminants and litter entering the environment.

Fitzroy Basin Region



FBA Region

FITZROY BASIN ASSOCIATION

1:3,000,000
(at original A4 size)

0 50 100 150

Kilometres

Coordinate System: Geocentric Datum of Australia 1994

Introduction

There is a growing consensus among Australians that working towards reinstating natural systems to help manage human impacts on the environment is imperative.

Restoration projects help the recovery of an ecosystem that has been degraded, damaged or destroyed by re-establishing its structure and function.

This chapter outlines the need for restoration activities and describes the purpose of, and how to use this guide.

Introduction

> There is a growing trend towards restoring natural systems

Need for restoration activities

There is a growing consensus among Australians, that working towards reinstating natural systems to help manage human impacts on the environment is imperative. In essence, a natural environment is resilient to change, helps mitigate against pollution and run-off, helps manage erosion and is resistant to invasive species. As such, there is a growing trend towards restoring natural systems, in particular along creeks and coastlines.

Restoration project objectives

Restoration projects help the recovery of an ecosystem that has been degraded, damaged or destroyed by re-establishing its structure and function. Ecosystem structure includes components such as:

» height and density of vegetation

» canopy cover

» appropriate species diversity

» habitat features.

Ecosystem function refers to the natural environmental processes that occur within the site, including:

» capacity for natural regeneration

» nutrient cycling processes

» the process of succession (where one community is replaced naturally over time by a more ecologically stable community).

One measure of a restoration project's effectiveness is the amount of continued human intervention required for the ecosystem to remain functional. As an ecosystem improves functionality, it will display greater resilience to disturbance and require less management; a fully functioning ecosystem requires little to no human interaction.

Restoration may involve identifying and protecting remnant habitat and improving areas of degraded habitat and linking them to areas of existing habitat. Protection and improvement may entail controlling invasive species and erosion, excluding stock or vehicles with fencing, removing pollutant sources and enhancing natural vegetation through seeding, direct planting or natural regeneration.

> a fully functioning ecosystem requires little to no human interaction

Progress of restoration works on a decommissioned haul road Fisherman's Landing Gladstone.

The site was deep ripped and seeded with a quick growing grass crop to minimise erosion.

Prior to planting the site was slashed and a mix of primary colonising species particularly Acacias, Eucalypts, Figs and assorted shrubs and ground covering herbs were planted. These plantings were mulched and maintenance involved brushcutting of weeds, re-mulching and follow up watering.

(Photos from top)
Post slashing May 2012, Post Planting Nov 2012, Progress of Revegetation July 2016.

In the Fitzroy Basin area, a principal goal of restoration projects is to improve the quality of water that flows into the World Heritage-listed Great Barrier Reef. The Great Barrier Reef contributes significantly to Australia's economic, cultural and social values. The Reef is under pressure from current and historical management practices that have impacted on water quality. These practices include land clearing, coastal wetland destruction, dam construction, coastal development and shipping. Inshore biodiversity has declined as a result of these modifications, and a recent study by the Australian Institute of Marine Science stated 50 per cent of coral cover has been lost from the Reef in the last 27 years.

Image of coral reef in the Capricorn-Bunker Group. (Source: Holly Lambert)

Purpose of this guide

Fitzroy Basin Association identified there are gaps in ecological restoration knowledge and skills, including advice available for small, community-based environmental projects. It is hoped this guide will act as a starting point for scoping and planning environmental projects, as well as provide advice for the types of restoration works recommended for the region. It has been built on the collective experience of local natural resource management practitioners through projects delivered across the region.

A range of individuals and organisations have undertaken ecological restoration across Queensland for many years. Each project has had different ecological aims, approaches, outcomes and successes. This guide is a dynamic document and users need to be aware that there may have been changes to legislation or other regulatory requirements since this guide's publication.

How to use this guide

This guide has considered the specific ecosystems and recommended restoration works in the coastal areas of the Capricorn and Curtis coasts, and urban waterways in Rockhampton, Yeppoon and Gladstone.

This guide consists of three parts.

» **Part 1: Scoping and planning** – outlines considerations and recommendations for scoping and planning ecological restoration projects. The scoping and planning considerations should be evaluated concurrently and any compromises need to be assessed.

» **Part 2: Restoration works** – provides recommendations for specific restoration works that are typically undertaken in coastal and urban waterways projects. This section outlines a variety of techniques including tips and how to quantify treatment and benefit areas of project works for evaluation and reporting.

» **Part 3: Ecosystems** – describes typical ecosystems found on the Capricorn and Curtis coasts, and Rockhampton, Yeppoon and Gladstone urban waterways. It also recommends appropriate restoration works for each ecosystem.

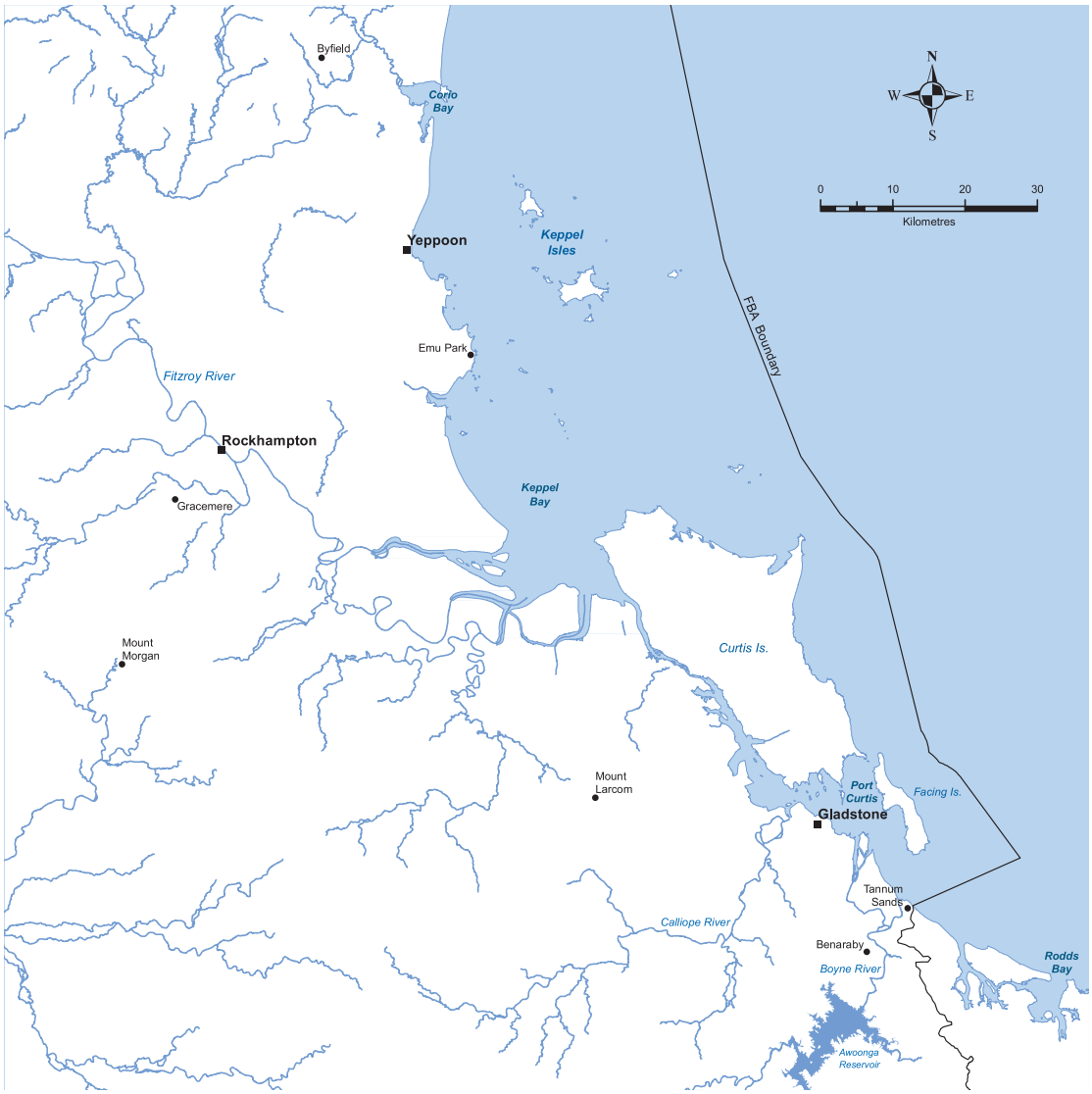
For first time users of this guide

It is a good idea to read through the introduction and the purpose and contents page for each chapter first. This will help you get a sense of the context and what is available in the depths of document. Once you have an idea what is in each chapter you should more easily be able to find relevant information in the guide.

Depending on the stage your ecological restoration project and your level of expertise, the information you seek in this guide will vary. If you have limited knowledge or are new to undertaking restoration works, it's recommended you initially use the Project Scoping and Planning chapter for support. It will then be possible to use the Restoration Works and Ecosystems matrix to identify the type of ecosystem you are working in and the recommendations for suitable restoration works for that ecosystem. If you have more expert knowledge, you may wish to use relevant sections as you want to find more information. A good place to start is the matrix as it gives a generic overview.

This guide is a living document. Restoration activities, technology, governance and many other factors are always changing and ecological restoration is an ever-evolving practice. As you trial new techniques and technologies, you can use the project planning checklist in Appendix B to document the information and procedure. You can then share this with relevant stakeholders, which could lead to better practice and improvements for local environments.

Focus area for this restoration guide



Part 1
Project scoping and planning

A range of factors should be considered to identify, scope and plan a restoration project. Some of these are crucial for prioritising restoration project sites and activities.

There is a strong link between scoping and planning factors addressed in this chapter, and these should be considered concurrently. It is important to note these considerations are not a sequential list of steps to follow and some may not apply to all projects. They simply provide an overview of the breadth of factors that should be assessed.

A project planning checklist is included at the end of this chapter, which provides a clear overview of all these factors.

Part 1: Project scoping and planning

Project scoping

A range of factors should be considered to identify, scope and plan a restoration project. Some of these are crucial for prioritising restoration project sites and activities. There is a strong link between scoping and planning factors addressed in here and in Part 2, and these should be considered concurrently. It is important to note these considerations are not a sequential list of steps to follow but simply provide an overview of the breadth of factors that must be assessed.

> Preventing unforeseen issues with the project can be avoided if comprehensive scoping and planning is conducted

By evaluating the range of scoping and planning considerations available, compromises to the intended project objectives, restoration works, and project site(s) may need to be made. It may be important to consider the intended restoration works and site ecosystem as part of scoping and planning; however, those factors may require more in-depth consideration and are addressed in other chapters of this guide. Preventing unforeseen issues with the project can be avoided if comprehensive scoping and planning is conducted, and compromises considered, prior to the project's commencement.

Timeframes

Effective restoration projects require long-term commitment; ecological restoration is a marathon, not a sprint. In most instances, five to 10 years are required to ensure a restoration project successfully improves an ecosystem. Ongoing maintenance and follow-up work is essential. This commitment should be considered when scoping a potential project as it can affect the capacity to fund or undertake a project.

Stakeholders

Stakeholders are the people and organisations involved or impacted by a restoration project and may include:

- land owners
- managing bodies
- traditional owners
- funding bodies
- natural resource management organisations
- local councils
- state and federal government departments
- local residents and organisations that may have an affiliation with or use the site.

Various government departments may also have an interest in project sites, particularly if they are a sensitive ecological area, involve endangered species or habitats, or occur in a waterway or coastal area.

Refer to Appendix B for a stakeholder analysis planning tool. This tool will help you:

- evaluate the nature of the stakeholder impact and the possible consequences for that stakeholder/group
- identify the stakeholder's importance by ranking their level of impact, influence and involvement
- develop a strategy for engaging with the stakeholder.

Urban planning considerations

Public safety

Project sites with public access need to prioritise the public safety. This will be especially important if the project involves using machinery or heavy equipment, conducting excavations of any kind or using chemicals such as herbicides. Safety mitigations may include signs and barriers to prevent access.

Image of Dolphin Sea Scouts installing barrier tape to mark the project site's boundary and warn participants of a steep undercut slope at Tannum Sands Beach. (Source: Conservation Volunteers Australia, Gladstone)

Infrastructure

Public infrastructure may include visible services such as roads, walkways and cycle networks, and less obvious utilities such as water, gas and sewage pipelines, and underground or overhead communication and power lines. Project sites with public infrastructure will require a plan to minimise service disruptions. Failure to locate public infrastructure can be costly and may have serious safety implications if they are damaged or disrupted.

Council work plan

When carrying out restoration works, project planning must be aligned with existing work plans for the area. Failure to check work plans may result in scheduled work plans affecting project sites. For example, if planning revegetation works, check that the site is not a dedicated easement for services. If the planting is haphazard and difficult to manage, work crews may just slash or mow over the site. Working with existing council work plans may benefit both parties. For example, in steep locations adjacent to creeks, a strip of riverine planting can help stabilise banks, improve water quality and remove the need for work crews to attempt to mow or slash thus making their job less hazardous.

Crime Prevention Through Environmental Design (CPTED)

Crime Prevention Through Environmental Design (CPTED — pronounced sep-ted) is a crime prevention strategy that outlines how physical environments can be designed in order to lessen the opportunity for crime (Queensland Police, 2017). The CPTED guidelines consider design and use, and identify which aspects of the physical environment affect the behaviour of people. They use these factors to guide the most productive use of space while reducing the opportunity for crime. This might include changing poor environmental design, such as street lighting and landscaping. CPTED concepts and principles are ideally incorporated at the design stage of a development. They can also be applied to existing developments and areas where crime and safety are a concern and may need to be factored into any urban project site, particularly when picking plant species that could conceal illegitimate activities or inhibit the effectiveness of lighting.

> Planning must be aligned with existing work plans for the area

Permit regulations

Before starting any restoration project, it is necessary to check the status of the planned project site to determine whether any special permits are required.

Land tenure

Land tenure refers to ownership. This can be broadly grouped into freehold land or leased land. In Queensland, land tenure falls under the *Land Act 1994* and is administered by the Queensland Department of Natural Resources and Mines (DNRM). Land administered under the Act is managed to benefit the people of Queensland. Freehold land is purchased from the State but the State still holds rights over minerals or other resources. 'Leasehold' land is State land that may be leased from the State under a variety of terms or agreements. Leased land is held in trust by the State and may be subject to terms and conditions that affect what activities can be carried out. In some circumstances, it may be necessary to obtain licences or permits before commencing works.

Riverine protection

Watercourses are currently managed by DNRM and the Queensland Department of Environment and Heritage Protection (EHP). Generally higher order streams (that is those that have a number of branches feeding into them) located closer to the coast will fall under the *Coastal Protection and Management Act 1995*, managed by EHP.

Any project that takes place in a waterway or impacts waterways, groundwater or on overland flow may require authorisation under the *Water Act 2000*. Most activities performed in the course of restoration works are exempt from authorisations; however, excavation or placing fill in watercourses may require obtaining a Riverine Protection Permit from DNRM to proceed and depends on the volumes involved. The minimum requirements for granting an exemption of a Riverine Protection Permit are outlined in Table 1.

It may be necessary to consult Business Queensland's Watercourse Identification Map to determine the status of the watercourse as the size and type of stream may affect the authorisations needed.

Protected plants

All Australian native plants in Queensland are protected plants under the *Nature Conservation Act 1992*. Clearing, growing, harvesting and trading in protected plants is regulated under the *Nature Conservation (Wildlife Management) Regulation 2006*. This legislation is designed to protect Australia's native plants while allowing for their sustainable use and harvest. Harvesting and growing species of 'least concern' is generally exempt from permit requirements. Plants listed as 'endangered', 'vulnerable', 'near threatened' or as 'special least concern plants' under the Regulation are considered 'restricted plants' and may require a licence to harvest or grow. Application for a licence will need to prove the harvest is ecologically sustainable.

EHP has surveyed and mapped the Queensland's vegetation and developed a protected plants flora survey trigger map. The map identifies high risk areas for protected plants, and is used to help determine plant survey and clearing permit requirements for a particular location.

A landholder may take particular protected plant parts, such as seeds or cuttings, for a conservation or revegetation program provided the species is not listed as restricted, the land to be rehabilitated is in the natural range of the harvested species, and the species harvested is not offered for trade. EHP has a Code of Practice that applies to harvesting, growing and trading seed and vegetative parts of protected plants for reproduction or regeneration purposes.

Check the status of the planned project site

Table 1

Exert from *Riverine protection permit exemption requirements* detailing the minimum requirements for granting an exemption of a Riverine Protection Permit (DNRM, State of Qld 2016)

Minimum Requirements

The minimum requirements outlined below must be achieved to be eligible for an exemption from having to apply for and obtain a riverine protection permit:

- The extent of the area required to carry out the permitted activity must be limited to the minimum area necessary to reasonably carry out the works.
- Sediment and erosion controls must be used.
- All areas of disturbed bed and banks must be stabilised to protect against erosion.
- All fill placed must be free from contamination (e.g. weeds seeds, oils, chemicals and other contaminants).
- Disturbed banks must be returned to a profile similar to the pre-disturbance condition.
- Natural stream bed controls or features that create natural waterholes (e.g. riffles, logs, sediment or rock bars) must not be lowered or removed.
- Any excavated material that is not removed as waste must be spread evenly within the bed and banks of the watercourse so that it does not interfere with the flow of water.
- All fill placed in the bed of the stream must not redirect flow into an adjacent bank.
- Access tracks or crossings must not interfere with the low flow of water.
- The invert of culverts or the deck height of a splash through crossing must be placed at or below bed level.
- All culverts placed within the watercourse must be aligned with the stream channel and placed as close to the centre of the watercourse channel as practical.
- All culverts placed within the watercourse must be of a sufficient size to ensure uninterrupted low flows and minimise the occurrence of blockage of culverts caused by flood-borne debris.
- Constructed access tracks (e.g. culverts or splash through crossings) must be provided with a scour apron and cut off wall on the downstream side sufficient to prevent bed erosion.
- All disturbed areas must be revegetated with trees, shrub and grasses endemic to the area, sufficient to re-establish a riparian environment and protect bed and banks from erosion.

Remnant vegetation

Under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act* there are also a number of ecological communities listed as 'threatened' at the national level. Within the Fitzroy Basin, these communities include

- Brigalow (*Acacia harpophylla* dominant and co-dominant)
- Coolibah-Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions
- Littoral Rainforest and Coastal Vine Thickets of Eastern Australia
- Natural Grassland of the Queensland Central Highlands and the Northern Fitzroy Basin
- Semi-Evergreen Vine Thickets of the Brigalow Belt (North and South)
- Weeping Myall Woodlands.

Protect Australia's native plants

The EPBC Act's list of Threatened Ecological Communities provides further information on composition, distribution and threats to each of these communities.

Cultural heritage

Under the *Aboriginal Cultural Heritage Act 2003* and *Torres Strait Islander Cultural Heritage Act 2003*, areas and objects that are significant to either Aboriginal or Islander custom, tradition or history (including contemporary history) are protected. The Acts recognise Traditional Owners must play a key role in matters of cultural heritage and also propose processes for identifying and dealing with areas and objects of cultural heritage in a timely manner.

Image of Indigenous stone tools used for opening shellfish, Main Beach, Facing Island.

Cultural heritage may include ceremonial places, scar trees, rock art sites, occupation sites, quarries and tool scatters; particular landforms such as caves, foredunes, lakes and wetlands; and certain vegetation types such as patches of rainforest. A duty of care exists for any activity that may impact an area or object of cultural heritage.

Cultural heritage listings and guidelines for engaging Traditional Owners as stakeholders are available on the Department of Aboriginal and Torres Strait Islander Partnerships website.

Native Title

Native Title refers to the communal, group or individual rights and interests of Aboriginal and Torres Strait Islander people in relation to land and waters, possessed under traditional law and custom, by which those people have a connection with an area that is recognised under Australian law. Areas of land in the Fitzroy Basin may fall under Native Title and these can be found by searching the National Native Title Tribunal website at www.nntt.gov.au. Carrying out works on areas under Native Title may require approval from the Native Title holders, claimants or their representatives.

Project planning

Comprehensive planning is essential to a quality restoration project. Good planning ensures

» works occur in an ordered, logical manner

» specific targets are met

» foreseeable problems are circumvented

» end goals are achieved in a timely and cost-efficient manner

» there is flexibility, should unforeseen issues arise.

A comprehensive project plan should consider follow-up works and plan for site maintenance beyond the current project's funding.

Unfortunately, not all restoration projects are planned correctly. It is hoped this chapter will help streamline the planning process and highlight the value of good planning.

Project objectives

It is important when planning a restoration project to identify what the desired outcome is; this is usually determined by the parameters of the project's funding source. For example, the objectives of a project funded to improve the quality of water flowing into the Great Barrier Reef may be to reduce sediment run-off, identify point-source pollution, and remove urban rubbish from the waterway. Removing a large number of weeds within the project site may actually decrease soil stability and increase sediment loads in surface run-off, resulting in the project failing to deliver the funding objective of improving water quality. In this instance, removing weeds is not an appropriate activity if water quality improvement is the sole objective.

Aligning a project with an appropriate objective prior to its commencement can be invaluable in guiding the project's direction and can help prioritise the order of works.

Prioritisation process

In most cases, funding and available resources will never be adequate to address all desired aspects of a restoration project, so it will be necessary to prioritise which works will be carried out, and in what order.

To prioritise areas that need to be addressed, it is necessary to consider a number of factors simultaneously, such as:

» habitat quality

» ecosystem services the habitat is providing

» broad landscape connectivity

» desired and likely impacts of works

» project objectives assessed against the funding source's criteria.

Please note, once prioritisation has been undertaken and restoration works are being planned it may be worthwhile to seek expert advice to predict the likely results after a source of ecosystem disturbance is removed. It is possible that once the disturbance is removed -natural environmental processes such as succession and recolonisation by native species may occur.

> Comprehensive planning is essential to a quality project

Using natural resource management principles to inform prioritisation

When making decisions there are a number of natural resource management principles that can support and inform decision making.

Patch size

The value of a particular site is dependent on a range of factors that determine its stability as an ecosystem and its value in relation to surrounding habitat. A small, narrow area of habitat is often more susceptible to environmental disturbances than a larger patch. The edges of a habitat patch are more prone to impacts from fire, weed infestation and other external pressures. Larger patches are more likely to sustain viable populations of plants and animals and are therefore more likely to be more resilient in the face of environmental disturbance. Therefore, the size of a habitat patch is a major factor in determining its importance in the broader landscape.

Connectivity

A second feature of an ecosystem's place in the greater landscape is its connectivity to other similar areas of natural habitat. The greater connectivity habitats have with each other, increases their overall value and function. Connectivity refers to the connections between a habitat and other areas of remnant habitat within the broader landscape. Connectivity also determines the ability of a species to disperse through the landscape. This can be via direct connection between adjoining patches of habitat or via narrow corridors of remnant vegetation linking separate habitats. Areas with greater than 75 per cent of their perimeter directly adjacent to surrounding intact habitats are considered well-connected. Areas linked by corridors rather than adjoining perimeters are less well-connected due to the impacts of edge effects on narrow corridors.

Context

A third feature of a habitat unit that determines its value is its place in the immediate landscape. This is calculated by assessing the percentage of remnant vegetation within a one kilometre radius of the habitat unit. This is referred to as context. A pocket of native vegetation is said to be very high context if it has greater than 75 per cent remnant or remnant regrowth habitat surrounding it. Context is low if less than 10 per cent remnant and less than 30 per cent regrowth vegetation is to be found within a one kilometre radius. Below this threshold, diversity in a habitat is usually insufficient to maintain a stable ecosystem.

Corridors

Corridors are passages of native vegetation that link areas of remnant or regrowth vegetation. They are an important aspect in a landscape of fragmented habitats as they may be the only means for dispersal of species between habitat patches. Maintaining these links may be the only way to ensure habitat patches function. Narrow corridors are often degraded by the impacts of ecological edge effects from fire, weed encroachment, waste dumping, or clearing. Corridors often follow drainage lines such as creeks and waterways, and these may be important for migration and movement of animals through the landscape. Queensland road reserves and stock routes also offer another avenue for wildlife corridor development.

High value habitat

A number of tools and plans exist that can identify various habitats that are of high ecological value. Mapping tools are useful; however, they may not be available for all ecosystems or to all restoration practitioners.

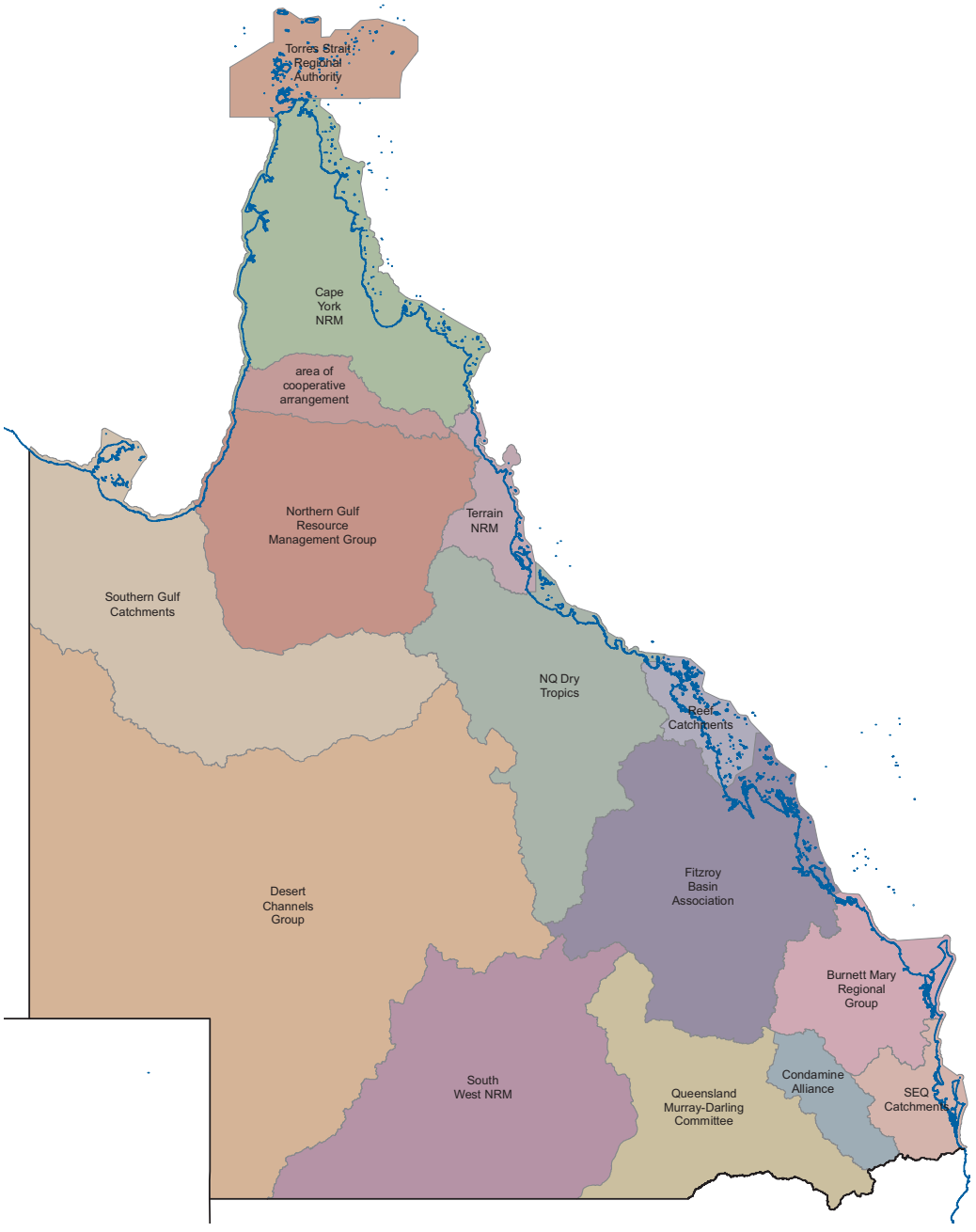
> Using natural resource management principles can support and inform decision making

Regional ecosystems

The Queensland Government's Regional Ecosystem Description Database classifies ecosystem types based on vegetation communities that are associated with a particular combination of geology, landform and soil type.

Most of the Fitzroy Basin falls within the Brigalow Belt Bioregion. North of Yeppoon is an area of Central Queensland Coastal Bioregion and in the Boyne-Calliope sub-region of the Fitzroy Basin is a small area of South East Queensland Bioregion.

Each regional ecosystem is identified with a three-part code: the first part refers to the particular bioregion, the second part refers to the land zone (simplified geology or substrate-landform) and the third part identifies the vegetation community based the dominant strata layer, which is the layer of plants that has the most biomass.



Map of Queensland's 13 Bioregions recognised under the regional ecosystem framework.
(Source: Department of Environment and Heritage Protection)

Knowledge of the project site's Regional Ecosystem type can be important as it can help:

» determine whether the Regional Ecosystem types are listed as 'endangered'

» guide environmental protection or restoration activities

» provide planning and management guidelines

» identify plant species that would normally be present

» guide fire management (where available) and bio-condition assessment

» identify remnant vegetation.

Regional Ecosystem maps in conjunction with the Regional Ecosystem Database Descriptions are valuable for predicting the vegetation and landform type in any area of Queensland. Regional Ecosystem maps are available at a scale of 1:100 000 (in some areas 1:50 000) for the entire State. They are regularly updated using aerial and satellite photography, geographic and landform data and extensive ground-truthing. This can be an invaluable tool for land managers to determine the relative size of the habitat patch, its connections to other patches of similar habitat, its susceptibility to edge effects and its context in the broader environment.

These tools can support decisions in assigning priorities to a particular site by determining:

» the project site's proximity to a Regional Ecosystem listed as 'endangered' or 'of concern'

» the relationship and interconnectedness between the project site and listed Regional Ecosystems.

> "Invaluable tools for land managers

A common goal of regeneration projects is to enlarge areas of remnant habitat or increase connectivity between habitats. Another high priority goal is to enhance the quality of degraded habitat to be similar to the its pre-clearing state. Connecting habitats via corridors of natural vegetation is often the only way to achieve these goals in a highly fragmented landscape.

Water Quality Improvement Plan

The Fitzroy Water Quality Improvement Plan (WQIP:2015) has been developed to guide improvement of the quality of water flowing from the Fitzroy Basin to the Great Barrier Reef lagoon. The plan identifies impacts on waterways, wetlands and adjoining catchments in an effort to inform on and minimise downstream effects. It is designed to prioritise areas for investment in water quality outcomes, as well as areas for ecosystem restoration. The plan, including the mapped priority areas, is available online at www.fba.org.au/wqip.

Directory of Important Wetlands Australia

A number of nationally important wetlands in the Fitzroy Basin area are listed under the Directory of Important Wetlands Australia (DIWA). This guide outlines the importance of specific wetland types and provides a baseline study for identifying wetlands at risk. It also discusses the need for developing a comprehensive network of protected wetlands. Wetlands listed under the DIWA are considered a high priority for restoration works.

Matters of National Environmental Significance

There are nine Matters of National Environmental Significance listed under the EPBC Act. These include World Heritage properties, National Heritage places, Wetlands of International Importance, Listed Threatened Species and Communities, the Great Barrier Reef, migratory species protected under international treaties, Commonwealth marine areas, water resources and nuclear actions. Any action that may significantly impact any of these nine matters requires authorisation under the Act.

The Fitzroy Basin is the largest catchment draining into the World Heritage-listed Great Barrier Reef. Additionally, the internationally important Ramsar wetlands of Shoalwater and Corio bays occur within the Fitzroy Basin, along with a number of nationally important wetlands. The region is also home to ecologically significant habitats and species that require protection and enhancement.

Key threatening processes

Under the EPBC Act there are 21 key threatening processes that impact on the unique environment of Australia and its biodiversity. Threats include competition and land degradation from pest animals and introduced plants, impacts due to predation by introduced species, impacts on plants and animals through introduced diseases and impacts caused by human activities such as climate change, marine dumping and land clearing.

Threat abatement plans

Threat abatement plans guide research and management actions to decrease the impact of a key threatening process as identified under the EPBC Act. These documents provide a national guideline to ensure the continued survival of native species and ecological communities affected by threatening processes.

Threatened species and ecological communities

Species or ecological communities that are identified as being extinct, extinct in the wild, critically endangered, endangered, vulnerable, or conservation-dependant may be nominated for listing as 'threatened' under the EPBC Act. A specialist scientific panel will assess the nomination then provide advice. If listed, the species or community will receive priority under the Act and its recovery will be promoted using conservation advices and species or community recovery plans.

It is important to note there are other systems available to identify the status of a species, such as the International Union for Conservation of Nature (IUCN) Red List. It is important to check which system you opt to use to determine the status of a species as there may be requirements from the funding body to refer to a particular system.

Conservation advices

Once a species or ecological community is listed under the EPBC Act a conservation advice may be generated. This provides information on the conservation status of, threats to, and the actions required to halt decline and facilitate recovery of the listed species or community.

Recovery plans

Recovery plans may also be developed under the EPBC Act to provide a definite management tool for listed species, communities or even for multiple species and communities, and designated regions. Recovery plans provide a planned and logical framework that describes key threats and identifies specific recovery actions. A recovery plan states what actions should be taken to protect and restore a listed entity and also how to manage and reduce threatening processes that impact on that entity.

Weeds of National Significance

The Australian Government has identified 32 weeds as Weeds of National Significance because of their invasiveness, potential for spread and their social, economic and environmental impacts. It was recognised that these species required a coordinated management approach at all levels; from land owners and managers and through all three tiers of government. A National Weed Management Strategy has been developed for each weed and provides advice on implementing a guided and targeted approach to all levels of the weed's management. State governments provide legislation, regulation and administration; however, local government and land managers and owners are responsible for weed management and control.

Site selection

Ultimately site selection should consider all of the preceding elements. This is why planning is such an important component of any environmental restoration project. The value of a project lies in its ability to address the designated objectives highlighted in the funding brief, the key threatening processes and maximise contributions to priority matters of environmental restoration.

It is good planning to have alternative sites identified in case the primary site is restricted by permit requirements, land tenure or the like.

Further considerations

Maintaining a clean worksite

Of the key threats outlined under the EPBC Act, there are three that are disease-related: dieback of native flora through infection with the root rot fungus *Phytophthora cinnamomi*, decline in amphibian numbers through infection with chytrid fungus and psittacine beak and feather disease affecting parrots. Myrtle rust is a fast-spreading plant disease that may also have significant impacts on Australia's native plants in the Myrtacaea family, which include myrtles, eucalypts, melaleucas and lilly pillies, among others.

When carrying out restoration works it is important to ensure the works do not spread weed seeds or disease agents into new areas. Adhering to quarantine procedures when working in known weed or disease habitats will help minimise weed and disease spread. Adequate planning project works may also help. Quarantine procedures can include:

- avoiding working in the infected area
- establishing buffer zones around affected areas
- working in one site per day if possible
- moving from areas least infected to areas more heavily affected
- washing down tools and equipment to prevent transmission
- using a disinfectant or sterilising agent when moving from infected areas to less infected areas
- washing clothing between site visits with detergent in hot water
- not moving infected material between sites
- ensuring weed seeds are contained and disposed of accordingly.

> it is important to ensure the works do not spread weed seeds or disease agents into new areas

Further information can be found in the Australian Government's *Arrive Clean – Leave Clean* publication.

Staying safe

Relevant qualifications and certifications

Depending on your site and works being undertaken, employees, volunteers or contractors may need to hold specific qualifications, certifications or licences. Before any work is undertaken, it is important to ensure any required licences, qualifications or certifications are held.

For example, commercial contractors applying pesticides in Queensland must hold a Commercial Operator's Licence (ACDC licence) issued under the *Agricultural Chemicals Distribution Control Act 1966*. Non-commercial operators are still bound by the Act; however, an ACDC licence may not be required. It is important to note however, that regardless of a non-commercial operator conducting any weed control using pesticides, a funding body, land holder or local government may insist that an ACDC-licenced operator is still required to undertake the works for safety reasons.

Risk assessment

While restoring the environment is an important task, it should not come at the expense of personal safety. Working outside and performing physical tasks under harsh climate extremes is a high-risk activity. All projects should incorporate a risk assessment process into the planning stages and proactively manage hazards and risks on the project site as needs arise. Conditions on a site may change rapidly and the health and fitness of workers may vary from day to day, as such, it is necessary to address risk management throughout the course of a project.

Table 2 lists some common hazards and risks often found on a project site, as well as some suggested controls. This list is far from exhaustive and the authors accept no liability resulting from omissions from this list. Workers must follow their own organisational guidelines to manage risk from project works. They may also need to adhere to risk management strategies of the landowner or land manager.

Conservation Volunteers Australia has established a safety management tool kit called *'In Safe Hands',* which is designed for use in practical conservation tasks.

Table 2

Project site hazards, risks and suggested controls

Hazard	Risks	Some suggested controls
Sun exposure	Dehydration, sun burn, sun stroke and heat exhaustion	Take regular rest and drink breaks, wear sun protective clothing, work in shade or during cool of the day
Venomous animals	Bites, stings and allergic reactions	Wear stout footwear and protective clothing, mark insect nests, line-walk site
Uneven terrain and slippery surfaces	Slips, trips and falls	Avoid hazardous areas of site, mark them, work across slopes rather than working up and down
Herbicides, fuels and other chemicals	Inhalation, ingestion, skin absorption, splashes into eyes and fire risk	Always follow product safety directions, wear required personal protective equipment, have suitable spill containment equipment available
Waterways	Falling in, venomous animals, crocodiles	Always advise someone if working near water, become "croc aware"
Physical tasks such as lifting, digging pulling	Manual handling injuries, strains sprains, repetitive strain injuries, crush and contact injuries, cuts and bruises	Ensure all workers are familiar with tools and their correct use, rotate tasks, use appropriate tool for the task
Sharp tools and cutting blades	Cuts, scratches and impact injuries	Use appropriate tool for task, ensure tools are maintained and workers trained in their use, maintain a suitable safe space when using swinging tools
Vehicles and heavy equipment	Accidents and noise impacts	Ensure only suitably qualified individuals operate equipment and vehicles
Vegetation – thorns, sap, tendrils	Puncture wounds, eye injuries, allergic reactions and crush injuries	Wear gloves and eye protection, Ensure only suitably experienced workers fell larger trees
Mechanical Tools – brushcutters, chainsaws, augers	Serious wounds, noise impacts, hearing damage, and repetitive strain injuries	Ensure only suitably qualified individuals operate equipment, ensure operators wear all appropriate personal protective equipment, keep a suitable safe distance away.
Soil and mulches	Infectious diseases and allergies	Allocate other tasks to susceptible workers, wash hands prior to eating or drinking, cover open wounds

Further reading

Markus, N 2009, *On our watch, The Race to save Australia's Environment*. Melbourne University Press, Melbourne.

The coastal indicator knowledge and information system
http://www.ozcoasts.gov.au/indicators/introduction.jsp

Maps produced by Queensland Government
https://www.business.qld.gov.au/business/support-tools-grants/services/mapping-data-imagery/maps

Assessing BioCondition
Eyre, TJ, Kelly, AL, Neldner, VJ, Wilson, BA, Ferguson, DJ, Laidlaw, MJ & Franks, AJ 2015, BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Manual. Version 2.2. Queensland Herbarium, Department of Science, Information Technology, Innovation and Arts, Brisbane.

Queensland's Regional Ecosystems
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/remnant-vegetation/

Species Profile and Threats Database, EPBC Act List of Threatened Ecological Communities
http://www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl

Fitzroy Water Quality Improvement Plan 2015
http://riverhealth.org.au/projects/fba-wqip/overview/

Directory of Important Wetlands Australia
https://www.environment.gov.au/water/wetlands/australian-wetlands-database/directory-important-wetlands

Fauna Sensitive Road Design: Wildlife Corridors
http://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Environment-management/Fauna-Sensitive-Road-Design-Volume-1/FSRD_4_WildlifeCorridors.pdf

National Wildlife Corridors Plan
http://www.olr.npi.gov.au/biodiversity/wildlife-corridors/publications/pubs/national-wildlife-corridors-plan.pdf

What is protected under the EPBC Act?
https://www.environment.gov.au/epbc/what-is-protected

Species Profile and Threats Database Listed Key Threatening Processes
http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl

Species Profile and Threats Database, EPBC Act List of Threatened Ecological Communities
http://www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl

Species Profile and Threats Database, EPBC Act List of Threatened Fauna
http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna#other_animals_extinct

Species Profile and Threats Database, EPBC Act List of Threatened Flora
http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora

Species Profile and Threats Database, Search Conservation Advices and Recovery Plans by NRM Region
http://www.environment.gov.au/cgi-bin/sprat/public/conservationadvice.pl
http://www.environment.gov.au/biodiversity/threatened/recovery-plans

Weeds of National Significance
http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/wons.html

Queensland protected plants flora survey trigger map
https://www.ehp.qld.gov.au/licences-permits/plants-animals/protected-plants/map-request.php

Arrive Clean Leave Clean
http://www.environment.gov.au/system/files/resources/773abcad-39a8-469f-8d97-23e359576db6/files/arrive-clean-leave-clean.pdf

In Safe Hands Toolkit
http://www.conservationskills.org.au/in-safe-hands-toolkit/

Queensland Police - Crime Prevention through Environmental Design
https://www.police.qld.gov.au/programs/cscp/safetyPublic/

CPTED - Essential features of safer places
https://www.police.qld.gov.au/programs/cscp/safetyPublic/Documents/CPTEDPartA.pdf

CPTED Guidelines for Queensland – Implementation Guide
https://www.police.qld.gov.au/programs/cscp/safetyPublic/Documents/CPTEDPartB.pdf

Queensland Police Safety Audit Program
https://www.police.qld.gov.au/programs/cscp/safetyPublic/audit.htm

Part ② Restoration works

The Society for Ecological Restoration International (SERI) defines ecological restoration as " ... the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."

The goal of undertaking any restoration works is to improve the structure and function of an ecosystem. Before beginning, it is important to understand how initial and follow-up restoration works will likely impact the ecosystem, and plan work so it can eventually be phased out when natural structure and function return.

The following chapters outline a range of recommended options, methods and tips to address common issues in degraded ecosystems. Advice on how to quantify restoration works for reporting purposes, identify differences between target and benefit areas and recommendations on further reading is also included.

Part 2: Restoration works

Monitoring Biodiversity

Biodiversity boosts an ecosystem's productivity and function; every species has an important role to play. A healthy biodiversity provides a range of ecosystem services, biological resources as well as social and economic benefits. It is important to monitor biodiversity before, during and after a project in order to determine current distribution of species and monitor any changes. There are many techniques to monitor biodiversity and this chapter provides a brief overview of some of these.

Biodiversity

Biodiversity is defined as the variation of life at all levels, including its composition, structure and its functions. This may include populations, species composition and genetic variability within a species (the gene pool). Structure relates to the physical habitat of the ecosystem and its components such as vegetation layers and soil structure. Function refers to how elements of the ecosystem work together, which includes the cycling of water, nutrients, carbon and energy, among others.

Monitoring biodiversity techniques

Biodiversity monitoring is the repeated observation and/or measurement of biological diversity in order to determine status and trend. Biodiversity is surveyed at a single point in time to determine current distribution and potentially abundance. Repeated monitoring allows for status and trends to be measured. Biodiversity is complex and as such typical biodiversity monitoring relies on indicators; measuring indicator species through quantitative and qualitative surveys can provide insight into changes in status and trends in the ecosystem, which reduces the cost of total biodiversity assessment.

Monitoring a project site should ideally capture seasonal changes as well as temporal changes (changes over time). If possible, surveys should capture a wet season and dry season prior to any restoration works being carried out. Subsequent surveys should be carried out after completing the restoration works and, where possible, at regular intervals afterwards, such as 6-monthly intervals. If a project is specifically targeting erosion, monitoring will be required after significant rain events, such as after 25mm rainfall in 24 hours. This post-rain event sampling should be repeated until the erosion control works are observed to be effective.

Photographic monitoring

Photo monitoring is an excellent method of keeping track of changes at a site over time. Establishing a photo monitoring point and keeping a photographic record is a simple way to document groundcover changes, height and density of vegetation, and events that may affect a project site over time. Modern digital cameras allow photos to be viewed in the field to ensure quality images are captured.

Photo monitoring is only of value however, if it is done systematically. For example, photos should be of the same area of the site, in the same direction, at the same scale and accompanied by some basic data on a photo monitoring data sheet, such as:

» site name and number

» site description

» date and time

» who did the photo monitoring and their contact details

» basic description of the prevailing weather conditions.

A landscape plot of panoramic photos show a general overview of the site and its surrounds. They can be a good record of site condition and show the changes in plant species composition over time. They may document impacts such as floods and bushfire. Spot photos taken of a 1 m x 1 m quadrat are useful to record groundcover and leaf litter percentage. Opportunistic photos can provide more detail such as species of interest, habitat features, pest species, disturbances, and so on.

To achieve the best lighting conditions for photo monitoring, it is preferable that photos be taken with the light behind the photographer (facing south if possible), at mid-morning or mid-afternoon and at the same time of day each time photos are taken.

Process

1. Select the photo monitoring site within the project site.
2. Mark the 'orientation point' and record its GPS location so it can be relocated in future.
    - » A star picket is commonly use to mark the orientation point, or select a highly recognisable feature such as a distinctive tree.
3. Complete the photo monitoring data sheet. Record date, time, site details, weather conditions.
4. Stand at the 'photo point' and take a landscape or panoramic photo of the site. A 'landscape orientation' photo is wider than it is high and 'panoramic' is a camera function that takes a sweeping, extra-wide shot.
    - » Aim to have the horizon divide the photo in halves (vertically) and the orientation point to divide the photo in halves (horizontally).
    - » Aim to have all objects in focus. Tip: focus the camera about a "third-way" of the image depth.
5. Repeat steps 3 and 4 at future photo monitoring. Ensure you bring your original image to ensure you line up all photos correctly. This is also helpful if other people are completing the photo monitoring.

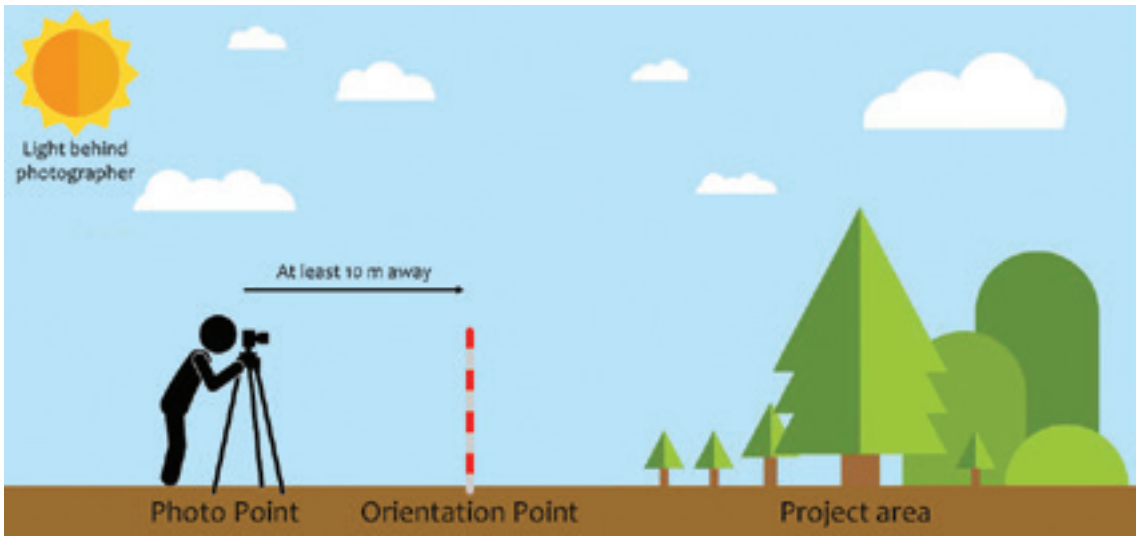
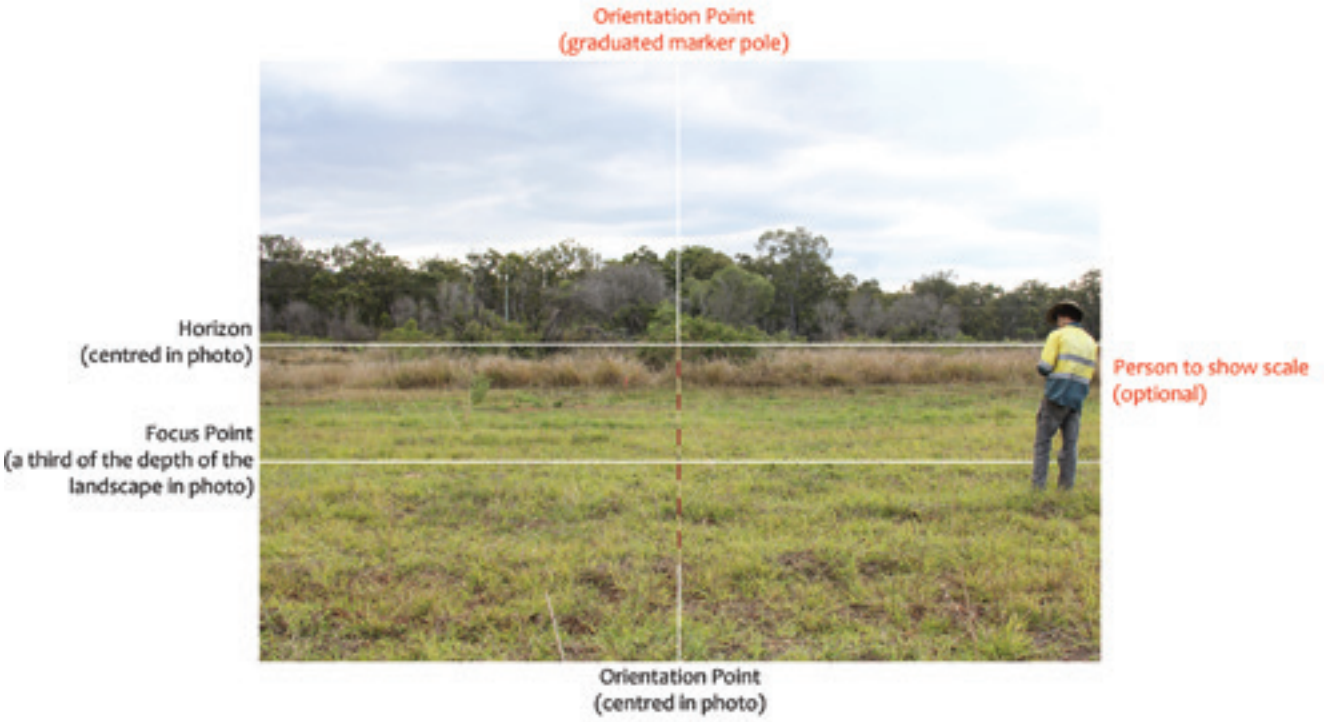


Diagram of establishing a photo monitoring point

> Photo monitoring is an excellent method of keeping track of changes at a site over time



Labelled image of a photo monitoring point, upper creek bank (landscape image). In this example there are two monitoring points opposite each other across the revegetation site. Photos are taken towards the opposite marker.

Labelled image of a photo taken at a photo monitoring site, Western Basin haul road, Gladstone (note the graduated pole used for scale).

Variations on technique

1. Using a second star picket spaced 5 metres (or a designated distance) from the plot marker post in a north-south alignment allows a central focal point of the plot to be captured. Align the southern star picket centre frame and take a photo with the camera zoomed fully out. This allows future photo monitoring to capture the same view.
2. Spot photos of 1 m x 1 m quadrats are an efficient method of documenting groundcover on the site. Take a photo from head height and aim near-vertically down to take in the 1 m x 1 m quadrat. For best results ensure the sun is behind you but aim not to have a shadow or feet encroach on the photo. Repeating these spot photos at the same point is crucial for standardising the monitoring protocol over time. Record site data, date, time, weather, as required.

Image of a spot photo taken of a 1 m x 1 m quadrat for sampling groundcover, leaf litter cover, and other variables.

Tips

» Photos should face south, where possible, as the sun will then be behind the photographer.

» Taking photos in the early morning or late afternoon will avoid the harsh contrasts between sunlight and shadow.

» A series of photos taken from the plot centre facing north, south, east and west can capture more variation across the site.

» Having a suitable scale in the photo can be useful. In landscape photos, a suitable scale can be a graduated marker post, a surveyor's pole, a person or vehicle. A camera lens cap, matchbox or pen can be used in spot photos or close-up images.

» Ensure any spot or opportunistic photos record site data, date, time, weather as required.

Image of a panoramic photo monitoring site, Moores Creek at Kershaw Gardens. Panoramic images can slightly skew the image's proportions; however, they show a greater area of the site

Biodiversity boosts an ecosystem's productivity and function

Ecological monitoring

Ecological monitoring includes bird surveys; plant and animal surveys; water quality monitoring; and soil, geology and hydrology investigations, among others. A full ecological survey of a site is generally beyond the scope of the average community-based restoration project and requires considerable expertise, specialist permits and accreditation. It can also be a costly exercise that could swallow the entire budget of any project. That is not to say regular monitoring or species surveys are not invaluable sources of information where limited monitoring is possible.

Image of Environmental Protection Notice sign advising the site is subject to environmental monitoring, as part of conditions imposed under an Environmental Impact Assessment, Western Basin Project Gladstone.

Plant and animal surveys

In Queensland, all native species are protected under the *Queensland Nature Conservation Act 1992*. It is imperative that the legalities of conducting plant and animal surveys and appropriate monitoring techniques are investigated prior to beginning any works. The Terrestrial Vertebrate Fauna Survey Guidelines for Queensland outlines the minimum requirements, standards, and appropriate practice for surveying terrestrial vertebrate fauna in Queensland.

Too often ecological surveys are restricted in the amount of time that can be spent on a site and as such, transient or shy species may not be observed. Regularly observing the species throughout a project can be a rewarding occupation for people working on-site and can add stimulus and focus to the work. It can also be an excellent means to learn or teach new skills and techniques in plant and animal identification and observation. These observations may also indicate how well the restoration activities are progressing. For example, many small bush birds are shy and prefer a dense cover of shrubs; they are often absent from more open sites. A developing presence of small bush birds in a restoration site may indicate the development of a functional shrub layer previously lacking at the site.

Image of echidna monitoring using wildlife infrared motion sensor cameras.

There are many different methods used to monitor plants and animals and it is important that some research is conducted prior to undertaking surveys. The Atlas of Living Australia aggregates biodiversity data and associated information on plants and animals in Australia. Select the species to be surveyed, for example, birds, fish, plants, reptiles, amphibians or invertebrates, and obtain some good reference materials for it, or engage a person familiar with the species.

Process

1. Scope out plants and animals in the intended area of interest by conducting research and gathering information from relevant databases.
2. Conduct a site visit and note species found at the project site.
3. Investigate appropriate methods for sampling selected plants or animals.
4. Check legality of the sampling method
    - » Are permits needed?
    - » Is a suitably qualified expert required?

5. Select an appropriate monitoring site within the project site. This monitoring site should be representative of the project site.
    - » Mark the site for future reference, using GPS, star picket, or a recognisable feature.
6. Document the procedure used, the weather conditions on the day and the species recorded.
    - » Record relevant and required data as detailed by the selected monitoring method.
    - » Record observations in a manner that can be accessed by future workers. There are some useful websites that allow people to document their observations. The Atlas of Living Australia is one such site that allows users to record species observed, generates species distribution maps and offers aids to identification and classification.

Tips

- » Permits
    - » Generally permits will **not** be required for surveys that just observe plants and animals (however, this should be checked in case there a specific requirements for specific species).
    - » Any process that interacts with a species, including capturing, handling, trapping, or netting will require permits.
- » Do not attempt to learn to recognise every species on the site in one day. Concentrate on a few species until each can be recognised comfortably before attempting to learn more. Investigate if there are any species that may be mis-identified in the project site's local area.
- » Keeping a notebook of observations and using it to jot down features of species observed can help with species identification.

Image of Birdlife Capricornia volunteers conducting bird surveys at Taroom Wetlands (Source: Allan Briggs, Birdlife Capricornia).

Resources

- » Atlas of Living Australia — biodiversity data and associated information on plants and animals in Australia
- » Birdlife Australia — Bird data and Atlas bird monitoring database and surveys project
- » FeralScan — allows people to map sightings of pest animals and record the problems being caused in local areas.

Water quality monitoring

A major aspect of restoration works in the Fitzroy Basin is to improve the quality of run-off water entering the Great Barrier Reef catchment. Poor water quality such as water enriched with nutrients; polluted with heavy metals, oils or chemical residues; or water carrying large amounts of suspended solids and high sediment loads is a major threat to the Great Barrier Reef's health. To assess the state of water entering the Reef, certain physical and chemical tests are regularly used to monitor water quality of water bodies within the catchment.

With increases in coal seam gas exploration and extraction, monitoring groundwater is also becoming increasingly important. A further aspect of water quality monitoring that is highly valuable in Australia's arid climate is monitoring salinity levels in waterways and groundwater.

The quality of a water body can also be gauged by using bio-indicator organisms. Often aquatic macroinvertebrates are used, such as aquatic insect larvae, snails and crustaceans. Fish communities can also indicate water quality.

Some water quality assessments require specialist laboratory analysis and water samples may need to be collected, stored and analysed using specialised protocols. This is generally beyond the scope of an average community-based restoration project.

Water quality parameters

Modern water quality meters incorporate a number of sensors grouped together to simultaneously record the physical and chemical parameters of the water body being tested. Typically temperature, pH and conductivity and dissolved solids are measured together as standard protocol. The ability to measure photosynthetic active radiation, turbidity and dissolved oxygen may be included in more expensive models. Meters will need regular calibration to ensure their accuracy in the field.

It is still possible to test basic water quality parameters without spending a small fortune on an expensive water quality meter. Measures such as pH of a water body can be sampled using impregnated paper strips that change colour in contact with acid or alkaline conditions. While these are more subjective tests, they can still give a general picture of stream health. Similarly, a turbidity tube or a Secchi disc can determine how much solid material is suspended in the water body. Both techniques determine turbidity by measuring the contrast of a black and white coloured disc.

Images of Gundoo Junior Rangers conducting water quality testing with Fitzroy Partnership for River Health. Top left: pH testing using pH strips. Right: testing turbidity with a turbidity tube. Bottom left: testing conductivity with a probe.

Image of CQUniversity staff using a combination water quality meter to assess water quality in a CQ waterway. This is a multi-probe meter that measures temperature, pH, conductivity, dissolved oxygen and photosynthetic active radiation.

Fish indicator species

There is current research investigating the fish species of some of the Fitzroy River's major tributaries to determine whether they can be used to indicate the levels of freshwater pollution from mine water discharges. Certain fish species, such as spangled perch, are very hardy fish and can survive in small farm dams, whereas other species, such as bony bream, are far less tolerant and succumb to low oxygen levels in a water body. An absence of certain species, such as mullet, may indicate the river is not connected to the estuarine environment, as mullet require saltwater environments to breed, in the same way barramundi do. Therefore, composition of fish species in a system can give a broad-scale picture of river health and connectivity. Research on South-East Queensland waterways concluded introduced fish species were a reliable first indicator of degraded riverine habitats.

Images of fish sampling as part of a CQUniversity study to consider fish as indicators of mine discharge water quality. Left: using a seine net. Right: employing baited box traps.

Macroinvertebrate indicator species

Macroinvertebrates are large invertebrate species that inhabit streams, ponds and other water bodies. They are important in monitoring river health as certain species are sensitive to aquatic pollution. An absence of these species can be an important indicator of the water quality of a particular site.

Species such as caddisfly larvae, mayfly nymphs and stonefly larvae and nymphs are very sensitive to pollutants in the water. Species such as water boatmen, freshwater snails and freshwater mussels are much more tolerant of poor water quality. Species composition can be an effective guide to the quality of the water at project sites.

Image of the contents of a baited box trap: numerous native fish (hardyheads and gudgeons) and some large diving beetles — a macroinvertebrate indicator species quite tolerant of water pollution. (Source: CQ University project: Isaac and Mackenzie rivers.)

Process

1. Conduct research and decide on an appropriate sampling protocol.
2. Decide on location of sample sites, ensuring access, presence of regular water, and that the site is representative of the impacts being tested.
    - » If sampling for mine discharge, sample sites must be downstream of mine discharge point, with control sample locations upstream of any discharges.
3. Plan timing of sampling.
    - » Sampling during peak flows in a flood event may give false indications of water quality.

   - » Also sampling in the midst of an exceptionally dry season will not give an accurate measure of water quality. Dissolved salts will be concentrated in drying pools due to water loss from evaporation.
4. Ensure operators are familiar with sampling equipment, meters and methodology.
5. Prepare any datasheets, sampling bottles, and any additives, reagents and preservatives prior to sampling.
6. Have macroinvertebrate keys ready and understand how to use them.
7. Calibrate or standardise all water quality meters and instruments prior to field use.
8. Record weather conditions on day of sampling.
9. Carry out monitoring with all care.
   - » Ensure no cross-contamination of samples.
   - » Ensure the calibration of all water quality meters and instruments is checked during field use.
10. Label all samples.
11. Analyse any samples taken as soon as possible after collection.
   - » Some samples may require refrigeration, addition of preservatives or reagents as specified in methodology.
   - » Samples may need assessing in specialised laboratories.

Tips

- » Certain water sampling procedures require specialised reagents and preservatives in storage bottles. It is essential to have samples accurately labelled.
- » Developing a reference collection of aquatic macroinvertebrates from a site can be a useful resource for future monitoring.
- » Liaising with other groups that regularly monitor adjoining waterways can help build a better picture of the whole catchment and its health.
- » The catchment's geology and soils can have a major impact on water chemistry, as can low flow and flood events. Noting local geology, flood and drought conditions, can help make sense of the data collected.
- » Surrounding land uses should be noted.
- » Heavy cattle use at a pool in a waterway can increase nutrient levels, affect suspended solids and alter dissolved oxygen levels significantly.

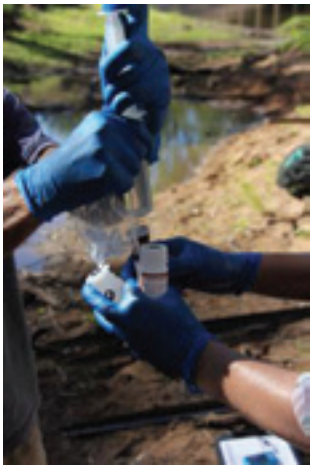


Image of water samples being taken for laboratory analysis for dissolved metals, Comet Weir.

BioCondition monitoring

BioCondition monitoring is used to measure how well a terrestrial ecosystem is functioning and approximate the biodiversity value of a unit of land at a local level. It was developed by the Queensland Herbarium as a quick and repeatable means of assessing the values of a particular habitat in comparison to areas of a similar benchmark habitat. The BioCondition monitoring method is designed for use by assessors who have a reasonable working knowledge of Regional Ecosystem mapping and vegetation assessment at the site scale. A full ecological survey of plants and animals may be required to quantify habitats more thoroughly; obviously these are more costly, time consuming and require greater expertise. The methodology used to perform a BioCondition assessment is, however, extremely useful for planning a monitoring regime for any project site and should be considered as a starting point for monitoring biodiversity (if not completing a full BioCondition assessment).

A range of natural attributes has been selected that are representative, quantitative, repeatable and reasonably easy to assess; these attributes are used as indicators to estimate a site's biodiversity value. Attributes are scored relative to reference values obtained from a series of 'best on offer' ecosystems representing the best available remnant ecosystems displaying minimal impacts. These reference values are termed 'benchmarks' and are selected based on site survey data from the Queensland Herbarium database, along with data obtained from field assessments of reference sites. Benchmarks are assigned to all vegetation communities within each Regional Ecosystem (RE). They are designed to reflect natural environmental variability in vegetation structure and species composition under a range of climatic and natural disturbance regimes across an RE. When conducting BioCondition monitoring, a local reference site should be included to assess for seasonal and geographic variations.

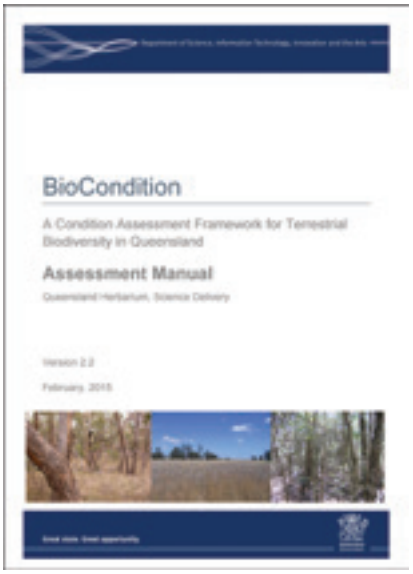


Image of BioCondition Assessment Manual

Table 3

BioCondition attributes used for BioCondition Monitoring in Queensland. (Source: Eyre et al. 2015)

Attribute	Brief description
Recruitment of dominant canopy species	Proportion of the dominant canopy (ecologically dominant layer) species with evidence of recruitment
Native plant species richness	The number of species expected in four life form groups, i.e. tree, shrub, grass, forbs and other species
Tree strata: › Canopy › Sub-canopy › Large trees	› Height – median height in metres › Cover – percentage cover (assessed as opaque crowns) › Diameter at Breast Height (DBH) – For large trees only; DBH threshold (cm). › Typical tree species for benchmark sites
Shrub strata: › Native shrub cover	› Cover – percentage cover (assessed as opaque crowns) › Typical shrub species
Groundcover: › Native perennial grass cover › Litter cover	› Cover – percentage cover (assessed as projected foliage cover) › Typical groundcover species
Coarse woody debris	› Total length in metres of woody debris > 10 cm diameter and > 0.5 m per hectare
Non-native plant cover	› Cover – Percentage cover of non-native plants › Typical non-native species listed with common names and declared pest status

Monitoring site selection and set up

Using the methodology for BioCondition monitoring provides a comprehensive repeatable means of assessing a site's biodiversity. The number of monitoring sites will depend on the habitat patch's size. For patches less than 60 ha two sites will suffice; sites greater than 500 ha should have five monitoring sites. Sites should be at least 50 m from edges and areas of disturbance such as roads, fire-breaks and watercourses. Survey sites should be 1 ha in size (that is, 100 m x 100 m).

Establish a 100 m long transect along the contour (not up and down the slope, if possible). This should be marked with GPS and permanent marker posts, such as star pickets or similar, as this will be the baseline for monitoring into the future. Mark the centre point of this transect; this is the plot centre and should be used as the site for photo monitoring. Walk the transect line and calculate percentage tree and shrub cover.

Measure 25 m from each side of the centre line to form a 100 m x50 m plot. In long linear habitat sites such as riparian zones, it may be necessary to double the plot length to 200 m and halve the width to a total of 25 m to maintain the survey plot size and ensure an adequate survey. In this area, count the large trees, calculate a median canopy height and enumerate tree species richness. Also calculate canopy recruitment rate.

From the 25 m mark on the central transect, mark out a 50 m x 10 m (5 m each side of central transect) sub-plot. Use this plot to calculate the cover of non-native species, and enumerate species richness of shrubs, grasses, herbs and forbs. From the same point on the transect, plot out a 50 m x 20 m sub-plot. Within this spot, count all the coarse wooden debris on the ground greater than 10 cm in diameter and 50 cm or more in length. This coarse debris is important habitat for reptiles, amphibians, insects and the like.

A series of five 1 m x 1 m quadrats should be spaced out from the 35 m mark on the central transect, alternating at 10 m apart along this line. These are used to assess native ground and leaf litter cover. It is a good idea to take photographs of these 1m2 plots so comparisons can be made of groundcover over time.

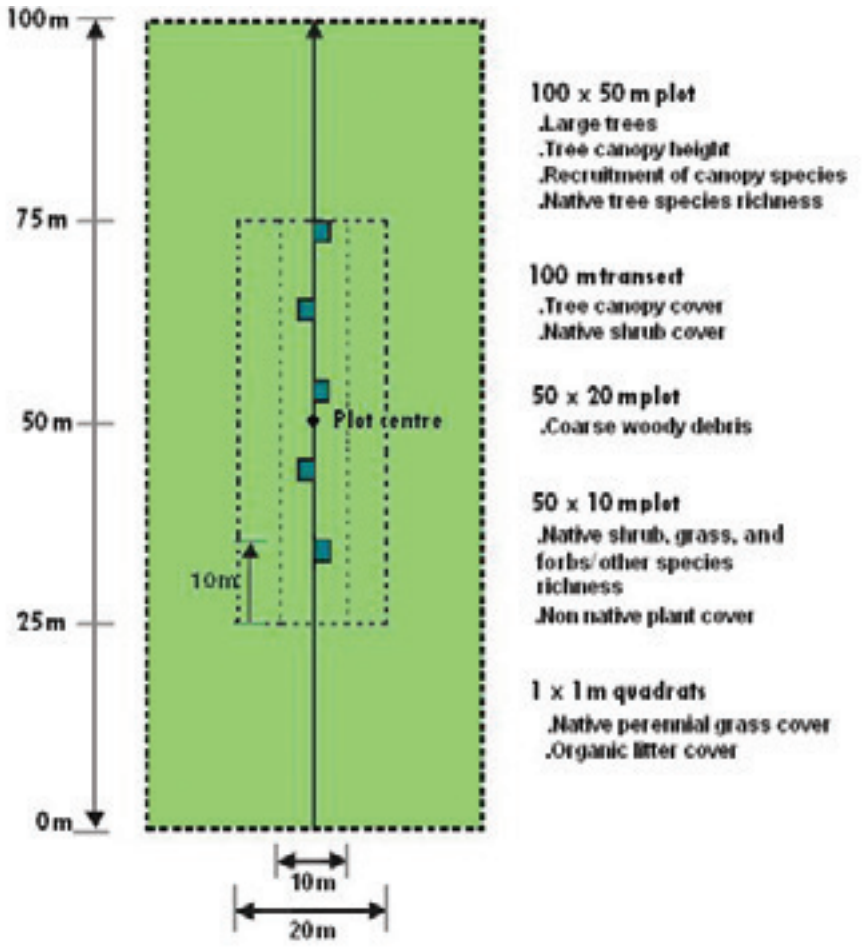


Diagram of site transect set up for BioCondition monitoring. (Source: Eyre et al. 2015)

Further reading

Eyre, TJ, Kelly, AL, Neldner, VJ, Wilson, BA, Ferguson, DJ, Laidlaw, MJ and Franks, AJ, 2015. *BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Manual. Version 2.2.* Queensland Herbarium, Department of Science, Information Technology, Innovation and Arts, Brisbane.
www.qld.gov.au/environment/assets/documents/plants-animals/biodiversity/biocondition-assessment-manual.pdf

State of Queensland 2015 DSITIA *BioCondition Benchmarks*
https://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

Eyre, T.J., Kelly, A.L., and Neldner, V.J. (2011). *Method for the Establishment and Survey of Reference Sites for BioCondition. Version 2.0*. Department of Environment and Resource Management (DERM), Biodiversity and Ecological Sciences Unit, Brisbane.
https://www.qld.gov.au/environment/assets/documents/plants-animals/biodiversity/reference-sites-biocondition.pdf

Fitzroy Partnership for River Health
www.riverhealth.org.au

Fitzroy Partnership for River Health – MyWater water quality data
www.riverhealth.org.au/report_card/community/

DSITIA *BIOCONDITION REFERENCE DATASHEET Version 2.1* Queensland Herbarium
www.qld.gov.au/environment/assets/documents/plants-animals/biodiversity/biocondition-ref-datasheet.pdf

Birdlife Survey Methods
http://www.birdlife.org.au/documents/TBN-searchtips.pdf

Kennard, MJ, Arthington, AH, Pusey, BJ and Harch BD, 2005. Applied Issues: *Are alien fish a reliable indicator of river health?* Freshwater Biology: Vol. 50, pp174–193

Queensland Department of Natural Resources and Mines, Waterwatch 2002, Waterbug and Riparian Vegetation Snapshot, Brisbane

Queensland Departmentof Environment and Resource Management, 2010. *Land Manager's Monitoring Guide; Photopoint Monitoring*, Qld Govt. Brisbane

Setting Up for Success, - a guide for designing, managing and evaluating projects, AND *Monitoring and Evaluation Workshop*, National Landcare Programme

"every species has an important role to play in biodiversity

Invasive weeds

It is estimated that weeds cost Queensland some $600 million in lost productivity and control annually. On top of this, weeds may also seriously impact on the services an ecosystem provides. Weeds may compete with native plants for space, nutrients and water, creating monocultures, reducing biodiversity and altering ecosystem resilience.

This chapter discusses the classification of weeds, various weed control methods and how to ensure successful weed treatment.

At the end of this chapter there is guidance on quantifying weed treatment for evaluation and reporting, by identifying treatment area and measuring the benefit area in an ecosystem.

What is a weed?

In simplest terms, a weed is a plant growing in the wrong place and, as such, is quite a subjective term. For this guide we will consider weeds to be plants that exist outside their natural range, and have the potential to spread rapidly, causing harm to the natural environment.

Many (but not all) weeds are exotic species. Of around 30,000 plants introduced to Australia, some 10 per cent have become weeds. Many species were introduced as ornamental garden plants, others as agricultural species intended to improve pasture, and others were accidentally introduced as contaminants of grain and in livestock shipments. While the majority of weeds are exotics, it is important to remember that native species can also become weeds. Cadaghi (*Corymbia torrelliana*) is a eucalypt native to tropical north Queensland. Widely planted as a street tree, it is starting to appear in bushland and waterways throughout the region.

Types of weeds

Weeds may range from being minor nuisance weeds that might appear in a path through to major infestations that can cover large areas, forming dense monocultures, altering fire regimes, affecting soil structure and composition and smothering vegetation communities.

Weeds of National Significance

There are currently 32 plants recognised as Weeds of National Significance by the Australian Government. These are considered the worst weeds in Australia based on their invasiveness, the cost to primary producers and the cost to the environment.

Image of *Lantana camara*, a Weed of National Significance.

State declared weeds

Each Australian state also has a classification system for weeds. *The Biosecurity Act 2014* provides a comprehensive biosecurity framework to manage the impacts of animal and plant diseases and pests in Queensland. Under the Act, Queenslanders have a general obligation to report biosecurity risks and local governments are required to establish their own biosecurity plans.

The *Biosecurity Act 2014* lists 'prohibited matter' in Schedule 1. Prohibited matter is biosecurity matter that is not found in Queensland, but would have a significant adverse impact on our health, way of life, the economy or the environment if it entered the state. Prohibited matter can be:

» diseases, viruses or parasites

» invasive animals and plants (e.g. pest animals or weeds)

» exotic marine animals, plants or diseases

» noxious fish

» insect pests.

If you become aware of prohibited matter or you believe, or ought to reasonably believe, that something is prohibited matter, you must:

» report it to Biosecurity Queensland on 13 25 23 within 24 hours, unless you are aware that it has already been reported.

» take all reasonable steps to minimise the risks of the prohibited matter and not make the situation worse.

» if you are unsure if it is prohibited matter, contact Biosecurity Queensland for more information.

The *Biosecurity Act 2014* lists 'restricted matter' in Schedule 2. Restricted matter is biosecurity matter found in Queensland and has a significant impact on human health, social amenity, the economy or the environment. Restricted matter can include:

» diseases, viruses or parasites

» invasive animals or plants (e.g. pest animals or weeds)

» noxious fish

» insect pests.

Specific actions are required to limit the spread and impact of this matter by reducing, controlling or containing it. There are seven categories of restricted matter. Restricted matter in Categories 1 and 2 must be reported to Biosecurity Queensland on 13 25 23.

Table 4

Required actions for reducing, controlling or containing restricted matter by categories.

Restricted matter category	Required action
Categories 1 and 2	Must be reported to an authorised officer within 24 hours of discovery in order that eradication (of Category 1) or containment, reduction and control (of Category 2) may be implemented.
Category 3	Must not be distributed. Includes by sale, as gifts, traded or released into the environment.
Category 4	Must not be moved.
Category 5	Must not be kept under your control.
Categories 6 and 7	Refer to the feeding of and humane destruction of animal and fish species.
It should be noted that some material may be classified under several categories and all restrictions under those categories must be applied.	

Locally declared weeds

Under the *Biosecurity Act 2014*, local government areas are required to develop their own biosecurity plans, which are similar to pest management plans). These plans identify invasive and pest species targeted for control at a local level. While a majority of these will be listed at a state level, there may be a number that are locally declared. Under local law, a landowner may be required to control these species on their land.

Image of Leucaena leucocephala showing large number of seed pods, a locally declared species. (Source: Gladstone Regional Council).

Common environmental weeds

An environmental weed may not feature as a declared weed but may be a localised problem in a particular habitat where it poses a threat to the natural environmental processes in that area. For example, silverleaf sunflower (*Helianthus argophyllus*) is a common environmental weed impacting dunes on the Capricorn Coast. Many of the common weeds targeted during restoration projects are environmental weeds.

Nuisance weeds

Nuisance weeds are minor weeds that pose little risk of environmental harm. It must be remembered that in ideal conditions even minor weeds can undergo population explosions that can impact on ecosystem health.

Recommended weed identification resources

- Australian Government – Weeds in Australia – Weed Identification Tools
- Queensland Government – *Biosecurity Act 2014*
- Queensland Herbarium – Assessment of invasive naturalised plants in south-east Queensland
- Capricorn Pest Management Group – Priority Weeds of the Capricorn Region
- Livingstone Shire Council – Weeds Management and Suspected Weeds Report
- Rockhampton Regional Council – Declared Plants (weeds)
- Gladstone Regional Council – Invasive Pest Plants

Why control weeds?

It is estimated that weeds cost Queensland some $600 million in lost productivity and control annually. On top of this, weeds may also seriously impact the services an ecosystem provides. Weeds may compete with native plants for space, nutrients and water, creating monocultures, reducing biodiversity and altering ecosystem resilience.

Weeds can produce large numbers of seeds or vegetative progeny, allowing for rapid spread and colonisation of new habitats. Aquatic weeds may block or choke channels, increasing the

Image of introduced grasses and lantana grow rampant along a telecommunications easement through eucalypt woodland generating high fuel loads, Double Creek, Calliope.

risk and impact of flood events. The breakdown of aquatic weeds speeds up the natural process of eutrophication, which can reduce oxygen levels in the water and lead to fish kills.

Weeds may alter fire regimes. Lantana and other woody weeds and exotic grasses can increase fuel loads and lead to hotter fires that can destroy native vegetation, and increase the risk to built structures and human life. Additionally, many weeds are toxic to stock and may have human health considerations. For example, parthenium weed has been associated with allergic reactions in humans.

Climbing weeds and vines such as cats claw creeper may smother native vegetation and cause branches and whole trees to fall in strong winds. Weeds can also alter soil structure and composition, making the land unsuitable for native regeneration.

Ensuring successful weed treatment

Understanding weeds

Prior to any weed control treatment it is important to understand the life cycle and habit of the target weed species. All plants can be divided into two large groups based on the number of seed leaves they produce. This characteristic is important when treating weeds because certain herbicides have been developed to target each group. Plants with a single embryonic seed leaf are termed 'monocots', and include grasses, sedges and rushes. All other plants with two embryonic seed leaves are termed 'dicots' and are also known as 'broadleaf' plants.

Image of parthenium (*Parthenium hysterophorus*).

Plants may be further categorised by their life cycle. Annual – an annual weed is characterised by a rapid life cycle. Annual weeds grow, set seed and die in one growing season, which is usually less than one year. Summer annuals germinate in Spring, grow rapidly during Summer then flower and set seed in late Summer before they die off in Autumn. Winter annuals germinate in late Summer or Autumn, grow slowly during Winter and then flower and set seed in Spring before dying off in Summer. Cobblers pegs (*Bidens pilosa*) and parthenium (*Parthenium hysterophorus*) are both examples of annual weeds. Parthenium can go from germination to producing seed in as little as four weeks. Seeds of many weed species may persist in the soil for several years giving rise to the old adage, "One year's weeds, seven years seeds!"

Biennial – refers to weeds that exhibit a lifecycle over two growing seasons. This is usually greater than one year but less than a two-year period. During the first season, the plant puts resources into vegetative growth. In the second season, it puts its resources into flowering and producing seed. Far fewer species display a biennial lifecycle than annual or perennial lifecycles. Some biennial plants may actually complete the biennial life cycle within a single year when conditions permit.

Image of singapore daisy (*Sphagneticola trilobata*) growing in a creek. (Image courtesy of Conservation Volunteers Australia, Gladstone.)

Perennial – refers to plant species that exhibit a lifecycle that extends over several years. Perennial weeds may reproduce vegetatively via stolons, runners, tubers and budding roots as well as through seeds. Perennials include woody broad-leafed plants such as lantana (*Lantana camara*), herbaceous broad-leafs such as Singapore daisy (*Sphagneticola trilobata*) and also grasses such as hymenachne (*Hymenachne aplexicaulis*) and Guinea grass (*Megathyrsus maximus var. maximus*).

Targeted vs broad treatment applications

The chosen treatment method will depend on the site, the weeds targeted, presence of non-target plant species, the desired project outcome, budget and the skills and abilities of the team carrying out the treatment activities. Targeted weed treatment is the control of an identified weed in a certain area. This may be necessary due to the presence of declared weeds, highly invasive weeds or species with the capacity to quickly dominate or transform the vegetation community. It may also be necessary to target particular weeds during periods of active growth. Broad treatment applications may be more cost-effective and less time consuming than a targeted approach but have the disadvantage that they may also target non- invasive species, kill off native regeneration and may leave the site bare of vegetation, thus exposing it to further weed colonisation or soil erosion.

Integrated weed management

The most effective means of weed control is to use an integrated management approach. No single method of weed control is fully effective against all weeds and no single approach will allow for successful regeneration of native plant species. Using a suite of treatments in a planned, integrated manner, can be more effective, more efficient, and less costly.

A system of integrated weed management might involve:

» slashing, grazing or burning to reduce biomass

» quarantine to prevent spread of the infestation

» initial blanket spraying of remaining weeds

» establishing groundcover competition to shade out weed species through planting and mulching

» introducing an effective biocontrol to reduce vigour of the target weed species

» follow-up spot spraying, brushcutting or manual weed control to allow natural regeneration of native species.

Season

From the understanding we have gained about weed lifecycles it becomes evident that treatment can be highly dependent on the season. Certain species may not be actively growing at certain times of the year or may, in fact, be absent in a vegetative form and present only as a seedbank in the soil or as underground tubers, rhizomes or the like. For most herbicides to work effectively, plants must be actively growing to ensure uptake and distribution of herbicides throughout the plant. For this reason, it is not advisable to treat weeds with herbicides under drought conditions when plants are experiencing heat or water stress as they will not actively uptake herbicide.

Also from our knowledge of weed lifecycles, it becomes apparent that treating weeds before seed-set may help reduce the soil seed bank. In situations where control may not be adequately managed in the time available, planning for control prior to seed-set may significantly reduce a weed's invasiveness.

Weather

Weather conditions may impact the choice of treatment methods. Rainfall and warmer conditions may stimulate unseasonal weed growth, requiring unscheduled treatment. While hand weeding may be easier immediately after rain when the soil is softer and allows whole plants to be removed with less effort, access to the site may be limited and prevent machinery operation due to slippery or boggy conditions.

Herbicide use should be confined to days when there is no immediate likelihood of rain and when there is, at most, only light breeze. Strong winds may cause off-target damage, and rainfall may wash herbicide off the plants, rendering it ineffective. Strong rainfall and run-off may also carry herbicide into waterways. It is, however, advisable not to spray during excessively hot or still days as target weeds may not adequately uptake herbicide, and fine aerosols may drift in the still conditions.

Site preparation

It is a good idea to map the project site during a project's planning stages. The mapping will be invaluable to identify areas of remnant vegetation, areas of priority weeds, erosion-prone areas and the site's other important features such as waterways or animal habitat such tree hollows. This map can be invaluable in the weed treatment process as it can allow a targeted approach to the weed control. By preventing an ad hoc approach it is more likely the weeds will be treated systematically, fewer weeds will be missed and outcomes will be more successful.

A method that works very successfully is to use a grid system or a series of transect lines to guide the weed treatment process. These can be physical lines such as ropes (if the size of the area allows) or flagging tape on vegetation, or compass bearings or GPS tracks if the area is large. Physical lines such as ropes work well in small areas with teams of weeders spraying or manually removing weeds. If a site is being weeded by hand, a second team can cross back over an area to pick up on any weeds missed by the first team.

Diagram for suggested plan for systematically covering a site to ensure effective weed control using a system of belt transects and teams re-covering ground already checked or treated.

Preparing the site prior to weed treatment may also involve 'tagging out' areas such as remnant vegetation, erosion prone areas and sensitive habitats to protect them from the weed treatment processes. This may be especially important if mechanical treatments are to be used, if the treatment is likely to cause spread of a weed species through dispersing seeds, or spreading plant diseases such as myrtle rust.

Site preparation may also involve slashing or brushcutting access tracks into the site, clearing fire breaks, erecting fences and removing excess biomass through crash grazing or mechanical means. Prior to spraying, brushcutting, slashing or other mechanical forms of clearing, it is a good idea to clear around desirable native plants by hand to prevent accidental damage.

It is good to keep in mind that disturbance to an ecosystem is a natural process that leads to succession; that is, the natural replacement of short-lived pioneering species by secondary and tertiary plant species. A climax community is generally the most stable community that can exist in a particular environment and this is generally the ecosystem most resilient to environmental changes.

Achieving a climax community requires the right mix of species and conditions and, as such, it is important to maintain areas of remnant habitat to allow natural regeneration from these areas. Often just controlling weeds along the fringes of remnant vegetation allows native plants to recolonise those areas. Over-clearing, on the other hand, may open up the ground to a new cohort of weeds. Careful planning and a more conservative approach to weed treatments may actually promote faster natural regeneration than more aggressive tactics.

Follow-up

Most weed infestations will not be controlled in a single treatment, and many may require years of follow-up treatment and maintenance. All project planning should allow a suitable follow-up weed control program. Follow-up treatments should be planned so they do not allow weeds to recolonise treated areas and preferably before seed-set. Follow-up treatment will be a necessary component of any good, integrated weed control plan.

Weed treatment techniques

There is a broad range of weed treatment options available and the treatment methods selected will depend on the site, the immediate surrounds, the project budget, the skill of the workforce, legislation and importantly the type of weed being targeted.

General observations

All treatment methods outlined assume that prior project planning has been carried out, that the areas to be targeted have been outlined in accordance with the project plan and that the weed species have been correctly identified and appropriate treatment methods selected. Any legislation governing chemical use must also be observed and legal obligations concerning working in endangered habitats, waterways and in regards to listed species must also be adhered to.

Trialling new techniques

Often the spread of weeds into novel environments means that new control techniques may need to be used. It is important to research the weed lifecycle and the intended treatment option thoroughly prior to trialling any new control technique. Too often ill-informed weed control efforts simply intensify or spread the outbreak.

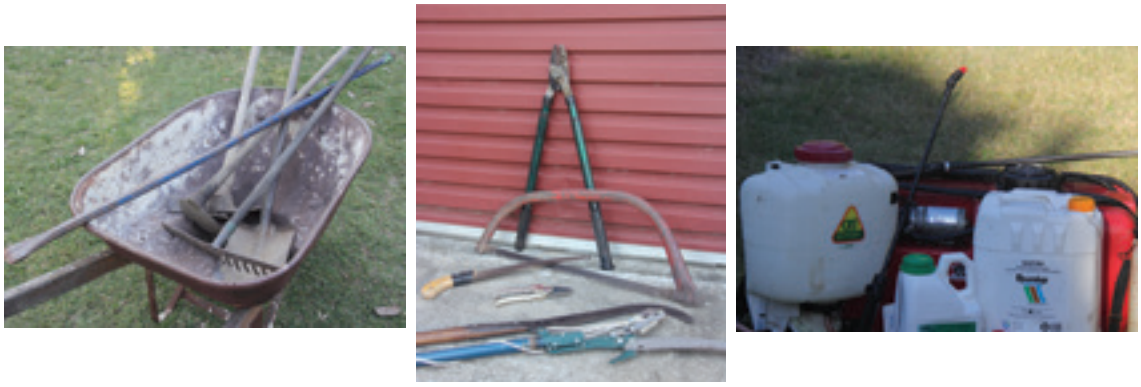
If trialling a new control technique, it is recommended that small plots be trialled in conjunction with a control plot that has similar vegetation, aspect, micro-climate and soil composition. This will help determine the effectiveness of the methods being trialled. It is also essential to adhere to any legislation governing use of chemicals. For example, using a chemical such as 2-4D may be effective against an aquatic weed infestation; however, it may contaminate the water, kill fish and extensively damage to an aquatic system.

Quarantine – preventing weed seed spread

The most important method of managing weeds is not to allow them the opportunity to establish in the first place. It is important to ensure any tools and equipment, machinery, soil, mulch, stock and so on, that is moved onto a site, is free of any weed seeds or vegetative plant material. Works on a site should, if possible, be structured to work from areas of least infestation into areas of heaviest infestation UNLESS immediate containment of a highly invasive species is required. Equipment leaving areas of heavy weed infestation should be carefully cleaned of any soil, plant trash and seeds. Areas used for clean-down should be situated away from natural drainages and be regularly checked for weed seed germination, and weeds subsequently controlled. Some seeds become sticky when wet so using a brush or leaf blower can be effective. The Queensland Department of Agriculture, Fisheries and Forestry advises on vehicle and machinery clean-down procedures.

Equipment that may be used for treating weeds

- General equipment
  - Flagging tape, GPS, notebook, camera, plant and weed guides
- Cutting equipment
  - Branch loppers, secateurs, hand saws, bow saw, chain saw, machete or cane knife, brush hook, pole saw, brushcutter
- Digging equipment
  - Mattocks, long-handled shovel, spade, crow bar, rake hoe
- Herbicide application equipment
  - Applicator bottles, hand sprayers, spray packs, knapsack sprayers, vehicle-mounted spray tanks, wick wipers
- Mechanical and heavy equipment
  - Tractor, slasher, boom mower, skid steer loader with mower/slasher or cutter bar attachments, bulldozer with stick rake, blade plough, cutter bar, scrub chains



Images of weed removal tools. Left: a range of cutting tools used for weed control. Middle: a range of digging tools used for grubbing weeds. Right: a range of chemical application equipment and herbicides available for weed control works.

Chemicals

General requirements for chemical use

Chemicals used for weed control are called herbicides. In Australia, a herbicide must be registered under the Australian Pesticides and Veterinary Medicines Authority (APVMA). This requirement controls how pesticides are used and helps prevent chemical resistance developing in target species.

Herbicide treatments for controlling weeds fall into two broad categories: selective and non-selective. As the names suggest, a selective herbicide targets a particular group of weeds, either dicots or monocots. A non-selective herbicide will be effective on both monocots and dicots.

Herbicides can be further categorised by their mode of action. Some work through direct contact with the plant, others are systemic and travel through the plant, and others have residual effects where they remain active in the soil to prevent the soil seed bank from regenerating. A herbicide is registered under APVMA for use with particular species although an 'off label' permit also exists for controlling environmental weeds in natural areas.

Material Safety Data Sheets (MSDS) are available for all chemicals, which **must** be made available to anyone using, storing or transporting chemicals. An MSDS outlines what the active ingredients of the chemical are, the hazards associated with its transport, storage and use. It also provides information on what to do if there is a chemical spill.

When using a chemical it is important to read all product documentation carefully and follow all safety directions on the product because:

» some products are not compatible when mixed

» some products are restricted from use in aquatic environments and waterways

» most products are controlled by legislation and may require an ACDC licence to use

» most products are restricted for use on certain species

» certain products may have a residual effect and it may be necessary to avoid contact with plants on the site for a specified period post-application

» some chemicals may have a withholding period and this may limit their use in public areas or if stock is present. Depending on land tenure/project partner/contractor requirements, people applying herbicide may need an ACDC licence. Fitzroy Basin Association requires the lead contractor to hold an ACDC licence. It may also be a requirement that signs are displayed stating that chemical application is being undertaken in the vicinity of treatment areas. Some land managers may require additional safety controls. For example, Livingstone Shire Council requires their weed control operators to post a spotter to ensure that members of the public are not inadvertently exposed to chemical overspray or residue during chemical treatment of public areas.

Chemical treatment methods

Cut stump and swab (cut and paint)

This method is useful for woody weeds with a defined stem and in areas where selective weed control is necessary. The weed stem is cut close to ground level (no higher than 15 cm) and an approved herbicide is either sprayed, swabbed or painted onto the cut stem as soon as possible after cutting (within 10 seconds). The herbicide is drawn into the plant's root system, killing it. Retaining the roots in the ground can help maintain soil stability and prevent erosion.

Process

1. Assemble the required equipment – secateurs, branch loppers, pruning saw, chainsaw, herbicide applicator bottle, personal protective equipment.
2. Mix the herbicide in the required ratio, into a suitable applicator bottle.
3. Identify the target weed.
4. Cut through the weed stem as close to the ground as possible (no more than 15 cm above ground level). This exposes the plant's cambium layer, which transports nutrients throughout the plant.
5. Apply herbicide liberally to the exposed cut stem **within ten seconds of cutting**. A plant's response to cutting will be to draw sap away from the cut, thus drawing herbicide into the roots. A plant will seal the cut with a sap plug soon after cutting, hence the need to apply herbicide promptly after cutting.
6. Treat any lateral stems of the plant in the same manner.

Tips

» Use a 500 ml spray bottle, shoe dye applicator bottle (with the sponge tip), a drip applicator or a narrow-necked bottle and paint brush as applicators.

» Adding spray marker dye to the herbicide mix can help track which stumps have been treated.

» Cut stumps horizontally as angled stumps can dry to sharp points and pose a risk of punctures to shoes and tyres.

» Remove leaf litter from around stems to ensure cut is close to ground.

» Scraping bark of exposed roots and from the stem can help herbicide uptake.

» Working in pairs ensures cut stumps can be treated almost immediately after the stem is cut and allows for task rotation to minimise fatigue and repetitive strain injury.

» Multi-stemmed weeds require all stems to be cut and poisoned.

Images of cut stump treatment. Left: Cut stump treatment of broad-leaf pepper trees. Stems are cut about 15 cm from the ground. Right: Concentrated herbicide mixture is applied immediately to the cut stem. With broad-leaf pepper trees, all stems must be cut and treated and follow-up is essential as the tree may re-sprout from the base or produce root suckers.

Images of tools and method for cut stump treatment. Top left: Equipment required for cut stump treatment of lantana. Herbicide is 1:1 Roundup Biactive. Top right: Removing stems to access the rootstock. Bottom left: Cutting main stems as close as possible to ground level. Bottom right: Applying herbicide immediately to the cut stem. Multi-stemmed species such as lantana must have all stems cut and treated, and follow-up treatment is usually necessary because some may re-sprout.

Images of cut and scrape technique.
Left: Using secateurs to remove bark layer. Right: Applying herbicide to the scraped stem.

Variations on technique

1. Cut, scrape and swab/paint – useful on climbing vines such as cats claw creeper.

Basal barking

This method is useful for treating woody weeds, especially thin-barked and multi-stemmed varieties, and saplings with trunks less than a 10 cm diameter. An oil-soluble herbicide is sprayed in a wide (30–40 cm) band around the trunk. The herbicide is absorbed into the plant, killing it, but leaves roots in situ, providing soil stabilising properties and reducing erosion on steep sites.

Process

1. Assemble all required equipment – knapsack or hand sprayer, personal protective equipment.
2. Mix an oil-soluble herbicide in correct ratio with diesel in spray pack.
3. Identify target weed.
4. Liberally spray a 30–40 cm wide band around the base of the target weed's stem or trunk. Cover stems completely and avoid over-spraying onto non-target species.
5. Ensure all stems of multi-stemmed species are sprayed

Tips

» Ensure herbicide is registered for the species being targeted.

Foliar spray

This technique is useful for large infestations of herbs, grasses, small shrubs and vines where a cost-effective, relatively quick and efficient method is required. Herbicide is diluted and sprayed onto foliage until the point of run-off. Herbicide is taken into the plant via the leaves. A range of equipment is available from hand-pumped sprayers through to large vehicle-mounted powered pump sprayers for treating larger areas. Selective or broad-spectrum herbicides may be used, depending on treatment requirements.

Process

1. Assemble all required equipment.
2. Identify target weed.
3. Dilute required amount of herbicide in selected spray receptacle (hand sprayer, knapsack, vehicle-mounted spray tank).
4. Follow all safety precautions as listed on product documentation.
5. Add spray adjuvants, wetting agents and marker dye, if using.
6. Adjust spray equipment to deliver a fine droplet. Too fine a mist runs the risk of aerosol spray droplets being windborne onto non target species
7. Spray target plants to point of run-off. Plant leaves should be wet but not dripping

Tips

- Avoid spraying unless in completely still conditions as aerosols can drift onto non-target species. Get droplet size correct.
- Avoid spraying near watercourses, adjacent to remnant vegetation or desired plants.
- Clear debris and weeds by hand from around non-target plants.
- Using a spray cone can help eliminate non-target damage.
- Adjusting the spray nozzle to a stream rather than a spray can deliver herbicide to harder to reach areas.
- Do not track through the sprayed areas. You may need to cut tracks into vegetation to obtain suitable safe access points.
- Some invasive species can develop herbicide resistance and may require a spray regime that uses alternate herbicides to achieve adequate control.
- Check product documentation carefully. Some spray additives can have health and environmental impacts.
- Spraying in a systematic pattern ensures no areas are missed.
- Remember, in dense vegetation above head height there is little air movement and the space you are spraying becomes a confined space, increasing your chances of chemical exposure through inhalation and skin contact.

Image of a team of volunteers blanket spraying a Singapore daisy infestation along Gladstone's Police Creek. (Image courtesy of Conservation Volunteers Australia, Gladstone.)

Image of a heavily protected, qualified volunteer preparing to spray invasive grasses at a project site along Police Creek, Gladstone. (Image courtesy of Conservation Volunteers Australia, Gladstone.)

Variations on technique

1. Blanket spraying – often used when first clearing a site of thick weed growth. This approach is non-selective and may accidentally kill non-target species such as native regrowth. It may be used when a site is being prepared for a mass planting. Often spraying opens the way for re-colonisation by another cohort of weeds.
2. Spot spraying – is a more selective approach, which can be utilised in more open infestations of weeds. When spot spraying weeds, there is less off-target damage and this method can be useful for follow-up control after initial treatments have removed the bulk of weeds.

Splatter gun

A splatter gun is a herbicide applicator that uses a gas pressure pack to deliver a stream of large droplets over target weeds. Due to the large droplet size and higher dose rate (usually a more concentrated herbicide mix than for foliar spraying) use of the splatter gun can achieve effective control of large infestations of woody weeds, especially those in hard to access areas.

Process

1. Assemble all required equipment.
2. Identify target weed.
3. Prepare herbicide according to product documentation and target species.
4. Using a broad sweeping action, spray a measured dose of herbicide over the target weed.
5. Repeat treatment may be required for large specimens.

Tips

» Follow-up spot spraying may be required to target regrowth.

» This technique generally uses less herbicide than foliar spraying.

» Using a splatter gun can be quicker and more efficient than foliar spraying.

Pellets

Some herbicide is available as pellets designed to be spread on the ground surface. These pellets dissolve with rainfall and percolate into the soil. They are ultimately taken up by the roots of the target weed. They tend to remain active in the soil and provide a residual effect.

Process

1. Assemble all required equipment.
2. Identify target weed.
3. Spread required dose under dripline of target species.

Tips

» Avoid using around non-target species

» Less effective under drought conditions

» May have a residual effect

» Not suitable for use in waterways

Manual hand pulling

Removing weeds by hand can be an effective means of controlling smaller infestations of smaller weeds. It is usually more effective if there is a group of weeders working in a systematic fashion.

Process

1. Assemble all required equipment – bags for weeds and seed heads, secateurs to remove seed heads, gloves, ropes or string lines, flagging tape, GPS.
2. Identify target weed.
3. Establish a baseline from which to work. This may be a line of existing vegetation, a natural feature such as a stream or road, or a GPS determined point. Mark the baseline using a rope, string or flagging tape along a vegetation line.
4. Work in a systematic fashion from established baseline.
5. Ensure weeds are removed roots and all.

6. It may be necessary to remove seed heads prior to weed removal. Cut off mature see heads and place in a bag for disposal.
7. Dispose of pulled weeds appropriately. This may necessitate removal in bags to an allocated dump, or composting on-site.
8. Dump sites should be checked regularly to ensure no reinfestation occurs.

Tips

» Removing and bagging seed heads prior to pulling may reduce seed spread.

» Work in a systematic pattern – using ropes to mark out belt transects in a weed patch and having weeders cross back over the previously weeded patch can be highly effective.

» Weeders need to be trained to recognise juvenile stages as well as mature plants.

» Tread lightly to prevent damaging native regeneration.

» Do not shake soil from plants that are seeding or which are capable of vegetative reproduction, such as mother of millions.

Variations on technique

1. It may be necessary to cut out the plant crown of deeper rooted species, or those in compacted soils to remove the point from which growth occurs. This may be achieved using a sharp knife or trowel and cutting out the plant's central growing point where it joins the roots. This technique is not suitable for species that sucker from the roots or have multiple growing points.

Volunteer team selectively weeding around native regrowth using the rope transect method, Lady Musgrave Island, Great Barrier Reef.

Manual grubbing

This technique uses hand tools to extract weeds from the ground; to turn over soil to create a bare patch for re-colonisation by natives, or to sow seeds of native species. Grubbing may be useful for removing larger woody species from sensitive environments when using herbicide is not an option.

Process

1. Assemble all required equipment – branch loppers (to clear access to rootstock), mattock, long handled shovel, gloves, eye protection.
2. Identify target weed.
3. If necessary, clear away low branches and stems to allow easier access to the rootstock.
4. Using a suitable tool dig around the root stock, cutting lateral roots where necessary. Try to minimise disturbance as much as possible.
5. Dig and lever target plant out of the ground.
6. Either remove all lateral roots or ensure they are buried deeply (to a depth of 15 cm or more). Aim to prevent re-shooting from lateral roots.
7. Refill hole and cover disturbed area with leaf litter or mulch.

Tips

» Best suited in softer soils such as sand and humus rich soils where digging is relatively easy.

» Manual handling injuries, especially repetitive strain type injuries, may be a risk.

» Do not over-clear as this can lead to soil erosion or a new weed crop re-establishing.

» Weeds can be left in situ to provide groundcover for establishing native plants and also provide a measure of cover for wildlife.

Images of a Conservation Volunteers Australia Green Corps team grubbing isolated lantana bushes along stream lines in Gladstone's Police Creek. Mattocks are used to sever roots and lever root stock from the ground. Roots should be removed where possible to prevent re-sprouting. (Images courtesy Conservation Volunteers Australia, Gladstone.)

Variations on technique

1. Hoeing small weeds can be used around native plants to reduce competition or to create a buffer to prevent off-target damage when spraying.

Biocontrol

Biocontrol – grazing

Allowing grazing animals to feed on weed species can be an economical way of controlling weeds. The technique is useful for removing excess biomass from weed species to curtail growth and allow natural regeneration to occur. It may also reduce the need for large amounts of herbicide. Weed areas may also be grazed for hazard reduction to reduce fire frequency or intensity and subsequently allow natural regeneration of fire-sensitive communities.

Image of grazing animals used to reduce weed infestation around a revegetation site, Double Creek, Calliope.

Process

1. Ensure target weed species is not likely to cause adverse impacts on stock welfare.
2. Ensure target area is adequately fenced to prevent stock wandering into non-target areas such as public areas or roads.
3. Ensure stock has adequate access to water.
4. Ensure stock are not carrying weed seeds on their coats or internally. Stock may need to be quarantined if they come from an area with different weeds to the target area. Introducing new weeds is to be avoided.
5. It is often best to introduce a large number of stock for a short period of time. Current advances in stock and land management suggest higher intensity grazing of a smaller area can be more effective than prolonged grazing over a larger area. A higher stocking density ensures the soil surface is cultivated by the animal's hooves, and their dung and urine fertilises and waters seed in the soil. Prolonged grazing tends to compact soil and allows animals to over-graze on more palatable species.
6. Monitor site regularly to ensure it does not become over-grazed, or the soil compacted.
7. Move animals to new pasture as soon as desired outcomes are achieved.

Tips

» Some weed species such as lantana and parthenium are poisonous to stock.

» Stock may need to be quarantined after exposure to weeds to prevent weed seed spread.

» Areas need to be securely fenced to prevent stock damaging non-target areas.

» Groundcover needs to be monitored to prevent over-grazing.

» Goats can browse woody shrubs and have been used to browse less poisonous varieties of lantana.

Biocontrol – bugs and fungi

Using biological agents to control weeds is a specialised field requiring extensive trialling under controlled conditions of selected control agents such as insects and mites and plant pathogens including fungi and rusts. Biocontrol agents must be rigorously tested to ensure they do not affect native species, and do not become a problem in their own right.

Process

1. Identify target weed.
2. Research available biocontrol agents for your target species.
3. Identify whether the climatic conditions are suitable for release of biocontrol agents.

Images of biocontrol for control of cats claw creeper: tiny little jewel beetles, Calliope. (Image courtesy of Capricornia Catchments.)

4. Source biocontrol agent registered for your identified target weed.
5. Release biocontrol agents into several locations of your target weed. Sites should be free of major disturbances such as fire or grazing animals.
6. Let the biocontrol agents eat/infect or do what they do!
7. Monitor the progress.
8. Inform and educate local landowners on biocontrol methods being used.

Tips

» Fungi such as plant rusts may require specific climatic conditions to be effective.

» Certain species may require further releases of the biocontrol agent as they may not thrive.

» Biocontrol agents do not usually destroy the weed but may reduce its vigour, hamper growth and hinder its capacity for reproduction by reducing seed set, or inhibiting germination, among other effects.

Image of a volunteer checking for active cactoblastis larvae in a prickly pear, Beecher, Gladstone. (Image courtesy of Conservation Volunteers Australia, Gladstone.)

Biocontrol – Groundcover competition

Many weed species actively compete with native species for water, light and nutrients. By establishing a good groundcover or by encouraging the growth of a dense native shrub layer, many weed species fail to thrive. Where a site has been cleared of an invasive weed species, establishing a short-lived, less invasive species such as an introduced grass, can be used to stabilise bare ground and prevent weeds from re-establishing from the soil seed bank. Assisted and natural regeneration of shrub and tree species can then occur, building habitat structure.

Process

1. Clear existing weed infestation using manual, or mechanical means.
2. Sow a quick-growing, short-lived non-invasive species such as Japanese millet. This will stabilise the ground and can out-compete weed species.
3. Direct seeding of native species in the initial seeding may help recruitment.
4. Monitor site and carry out follow-up weed control and tube-stock planting as required.

Tips

» Careful selection of the seed is required to ensure adequate ground cover competition.

» Groundcover establishment may be aided through fertilisation and watering.

» This technique may be used on quite large-scale projects and is commonly used for mine site rehabilitation and road works, for example.

Variations on technique

1. Using a mulch layer or a weed mat may also be used as groundcover. In fact, one of the primary aims when mulching around plants is to help suppress weeds that would compete with the desired plants.

Image of quick-growing cover crop of Rhodes grass sewn on this site to help prevent weed germination and minimise erosion, Western Basin haul road, Gladstone.

Images of using groundcover competition. Left: Hay mulch used for weed suppression around native plantings, Double Creek Calliope. Right: Geofabric jute mat used to suppress Mexican petunia, Capricornia Catchments, Boat Creek project, Yarwun.

Fire/thermal weed control

Fire can be an excellent tool to control certain weed species. However, it is non-selective, can be dangerous and difficult to control. Certain habitats are extremely fire sensitive and should not be burnt.

Process

1. Notify all neighbouring landholders of your intention to burn.
2. Organise a fire permit for the area you wish to burn through the Rural Fire website.
3. Ensure adequate firebreaks are installed around the area to be burnt.
4. Check weather forecast and fire danger forecast. Do not burn when there is a high fire danger or strong winds forecast.
5. Assemble all required personnel to assist with the burn. Ensure personnel are adequately trained in fire-fighting techniques and operation of equipment.
6. Assemble all required equipment – this will need to include fire-fighting equipment as required by your fire permit.

7. Notify the relevant government agencies of your intention to burn (FIRECOM).
8. Light fire.
9. Do not light large areas all at once; patch burning encourages habitat diversity.
10. Monitor fire and damp down any fires in hollow trees and large logs.
11. Ensure the fire is out or safely contained before leaving site.

Tips

» Ensure you have a fire permit and have notified all relevant authorities.

» Fire should not be used in fire-sensitive vegetation communities such as rainforest, softwood scrubs or on beach foredunes.

» Fire can be unpredictable and dangerous. Exercise all care when using fire as a management tool.

» You may be held legally responsible for any damage caused by uncontrolled fires.

» Fires are often lit in the late afternoon as evening dew can help reduce fire intensity.

» Fires should be lit in such a way that wildlife can escape into unburnt habitat.

» Fires may stimulate native regeneration of fire-adapted species.

» Fires in non-fire adapted communities may trigger re-establishment of a new weed cohort.

For further information, read the Queensland Government's Fire Management Guidelines and SEQ Fire and Biodiversity Consortium.

Variations on technique

1. Spot fires – Small infestations of fire-sensitive weeds may be targeted using small spot fires. These may not require permits, providing the area burnt is no greater than 2 metres in any dimension.
2. Thermal weed control may also involve using steam to kill weeds in sensitive environments.
3. Another method of thermal weed control may involve placing sheets of black builder's plastic over weed infestations for a number of days. Sunlight on the plastic causes the temperature underneath to rise to lethal levels. Piling less invasive weeds up into piles and allowing them to compost may have a similar effect with the heat of decomposition actually killing the weeds and seeds as well. It will be necessary to monitor weed piles to ensure no residual seed has survived the composting process.

Images of fire control. Left: A hazard reduction burn of eucalypt woodland with scattered lantana understory. Right: A small spot fire to control mother of millions, Double Creek, Calliope.

Mechanical control

Mechanical – brushcutting

Using a petrol-powered grass trimmer or brushcutter can be an effective means of reducing the vigour of invasive weeds, allowing native plants to recolonise an area.

Process

1. Ensure machine is in a safe operational state, with all guards and safety features in place and functional. Read and understand the operation manual prior to use.
2. Operators should be familiar with the machine and have received training in its safe use. If fitted, harnesses should be adjusted to give a snug fit and to ensure a comfortable operating stance.
3. Assemble all required equipment – brushcutter with suitable cutting head (a steel blade is ideal for work in heavy infestations and dense weeds). At a minimum, safety equipment should include steel-capped boots, long trousers, long sleeved shirt, hearing protection and safety glasses. A face shield or mesh visor is also advisable. Flagging tape may also be needed.
4. Identify non-target species and carefully clear around these by hand if necessary. Mark any desired plants with flagging tape.
5. Scan site for rocks, star pickets and old fencing materials. These can damage or entangle the blade.
6. Ensure area is clear of bystanders, follow all operational considerations and start brushcutter.
7. Using a scythe-like motion swinging gently from the hips, begin to cut into the designated treatment areas. The swinging motion should allow cut weeds to fall beyond the path of the cut. It may be necessary to top the weeds before cutting them down to the desired height. Avoid contact with large stumps, logs, etc., as these may damage the machine.

Tips

» Warning signs may be required if public access is likely.

» Brushcutting weeds that reproduce vegetatively may cause them to spread.

» Brush-cut material may be used as mulch to help prevent weed regeneration.

» Brushcutting will generally require regular follow up to prevent regrowth.

Images of brushcutting. Left: Brushcutter with blade attachment for cutting heavy vegetation. Centre: Using a brushcutter to cut access into a lantana thicket. Right: Brushcutting to control weeds around a revegetation site, Western Basin haul road. Note: operator wears safety equipment.
(Images courtesy of Conservation Volunteers Australia, Gladstone.)

Mechanical – slashing

A tractor or skid-steer-mounted mower or slasher can effectively reduce dense weed infestations covering larger areas. Usually a contractor or council operator familiar with the equipment is engaged to carry out this work. Slash can be left on-site as mulch to help prevent weed regrowth.

Process

1. Engage suitable contractor.
2. Explain desired outcomes fully with contractor. Having the contractor visit the site, and a project plan in place, can help explain what the project aims to achieve.
3. Clearly define non-target areas with flagging tape or barriers.
4. Identify areas where it may be unsafe to operate machinery. These areas may be flagged as well.
5. It may be necessary to place warning signs if public access is likely.
6. Ensure the operator provides a weed hygiene declaration on their equipment. This is a written notice designed to stop the spread of certain Class 2 weed species.
7. Follow operator's safety directives once they are active on site. This may mean suspending work in the immediate area until the contractor has finished.

Tips

» Slashing weeds that reproduce vegetatively may cause them to spread.

» Ensure machinery is cleaned when finished to prevent spreading weed seeds.

» Large machinery can cause soil compaction and excessive soil disturbance, so may not be a suitable option for all sites.

» Suitable access to the site will be required.

» Equipment may not be able to access all areas of the site due to slope and terrain. These areas can act as reservoirs for weed reintroduction, if not checked.

Image of slashed pasture grasses prior to revegetation project. The site was slashed by a tractor-mounted slasher and then deep-ripped prior to planting, Stowe Park, Calliope. (Image courtesy of Conservation Volunteers Australia, Gladstone.)

Mechanical – dozing, stick raking, Ellrott blade ploughing

For large areas of heavy weed infestation, especially large woody weeds, using blades fitted to dozers, tractors or skid steer loaders may be necessary. Blades can be a simple pushing blade or have specialised cutter bars fitted to cut through roots below ground. Blades may be towed or pushed, depending on mounting options and blade types. Like slashing, this management technique is often the realm of specialist contractors who have their own equipment. It is important to note, however, that contractors may not be familiar with best practice environmental restoration work so will need briefing and guidance about the desired project outcomes.

Process

1. Engage suitable contractor.
2. Explain desired outcomes fully to contractor. Having a project plan and the contractor visit the site can help explain what the project aims to achieve.
3. Clearly define non-target areas with flagging tape or barriers.
4. Identify areas where it may be unsafe to operate machinery. These areas may also be flagged.

5. It may be necessary to place warning signs if public access is likely.
8. Ensure the operator provides a weed hygiene declaration on their equipment. This is a written notice designed to stop the spread of certain Class 2 weed species.
6. Follow operator's safety directives once they are active on site. This may mean suspending work in the immediate area until the contractor has finished.

Tips

» These techniques create large amounts of disturbance on-site and may lead to soil erosion problems. It may be necessary to leave buffer strips adjacent to erosion-prone areas and limit the use of machinery in these sensitive areas.

» Large machinery can cause soil compaction and may not be a suitable option for all sites.

» Ensure machinery is cleaned when finished to prevent spreading weed seeds.

» Suitable access to the site will be required.

» Equipment may not be able to access all areas of the site due to slope and terrain. If not checked, these areas can act as reservoirs for weed reintroduction.

Image of a dozer fitted with rake that could be used to mechanically remove weeds from a large area.

> prior to any weed control treatment it is important to understand the life cycle and habit of the target weed species

Quantification

The project area is the entire area in which the project will have its focus. This may be an area significantly larger than the actual treatment area(s).

The treatment area is the place where actual physical works take place, for example, the area actively sprayed with herbicide.

The benefit area is a measurement of the area that actually attains some measureable benefit from the treatment carried out. It is possible the benefit area may be larger than the treatment area. It is essential there is empirical, realistic, observable evidence supporting the claimed benefit area.

For example, if an entire creek catchment is identified as a significant ecosystem, this creek becomes the project area. An isolated infestation of rubber vine in the headwaters is identified as a treatment priority. This area is defined as the treatment area. The benefit area from this treatment of the rubber vine may extend well beyond the range of treatment as rubber vine is spread by wind and water.

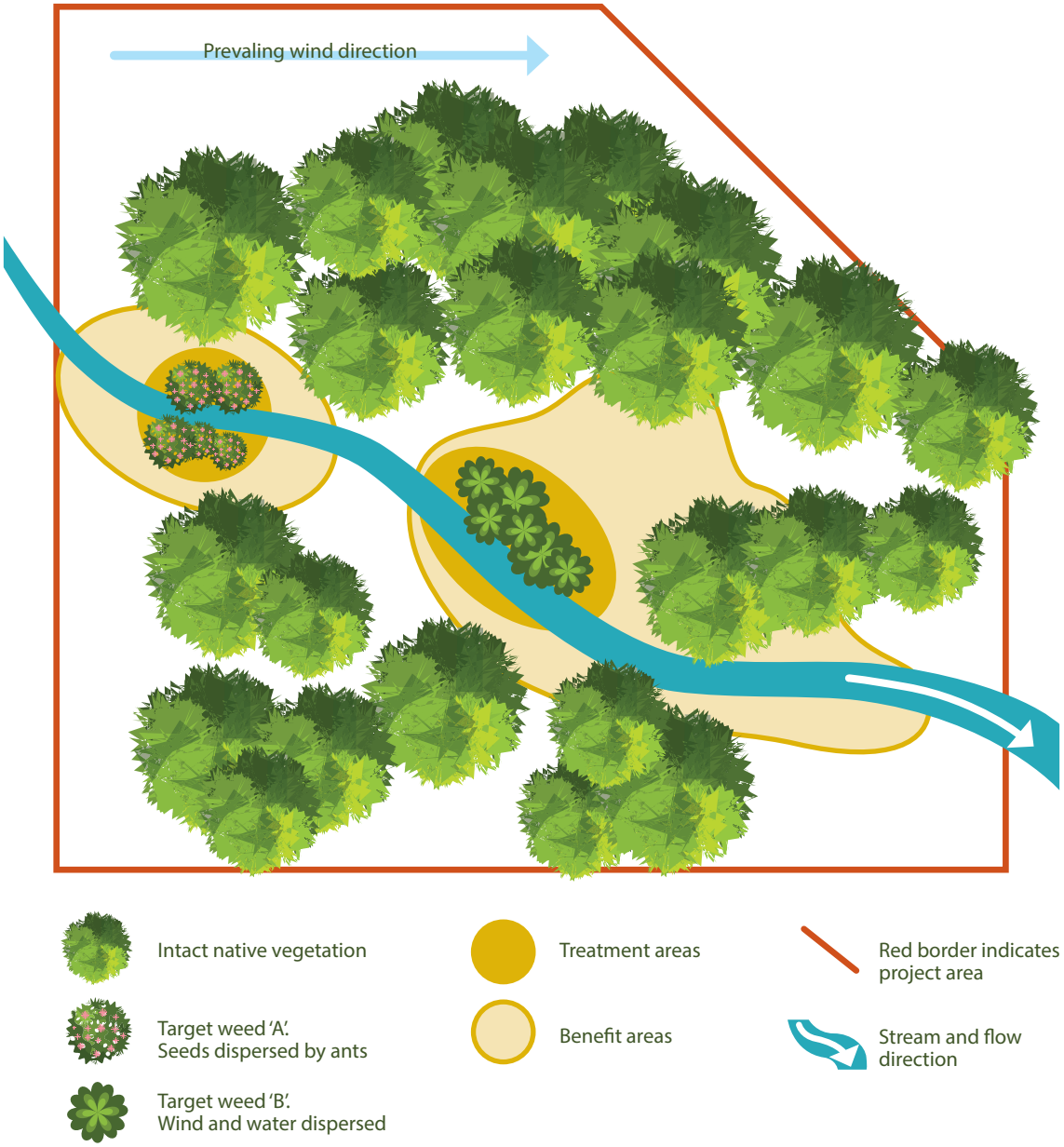


Diagram showing project area, treatment area and benefit area for two weed. species that are spread in different ways.

For Species A, the seeds are dispersed by ants so the benefit area of carrying out weed control on Species A is equivalent to the distance the harvesting ants carry seeds from the infestation.

For Species B, the seeds are transported by both wind and water so the benefit area is a combination of both the area downwind of the infestation and the area downstream along the streambanks. The benefit area downstream counts as far as the highest flood level away from the stream and the first major bend in the stream as this bend causes the stream to deposit its load.

Without treatment, the weeds invade the intact native vegetation, and as both weed species are capable of increasing fire risk and fire intensity they increase the likelihood of fire damage to the native vegetation.

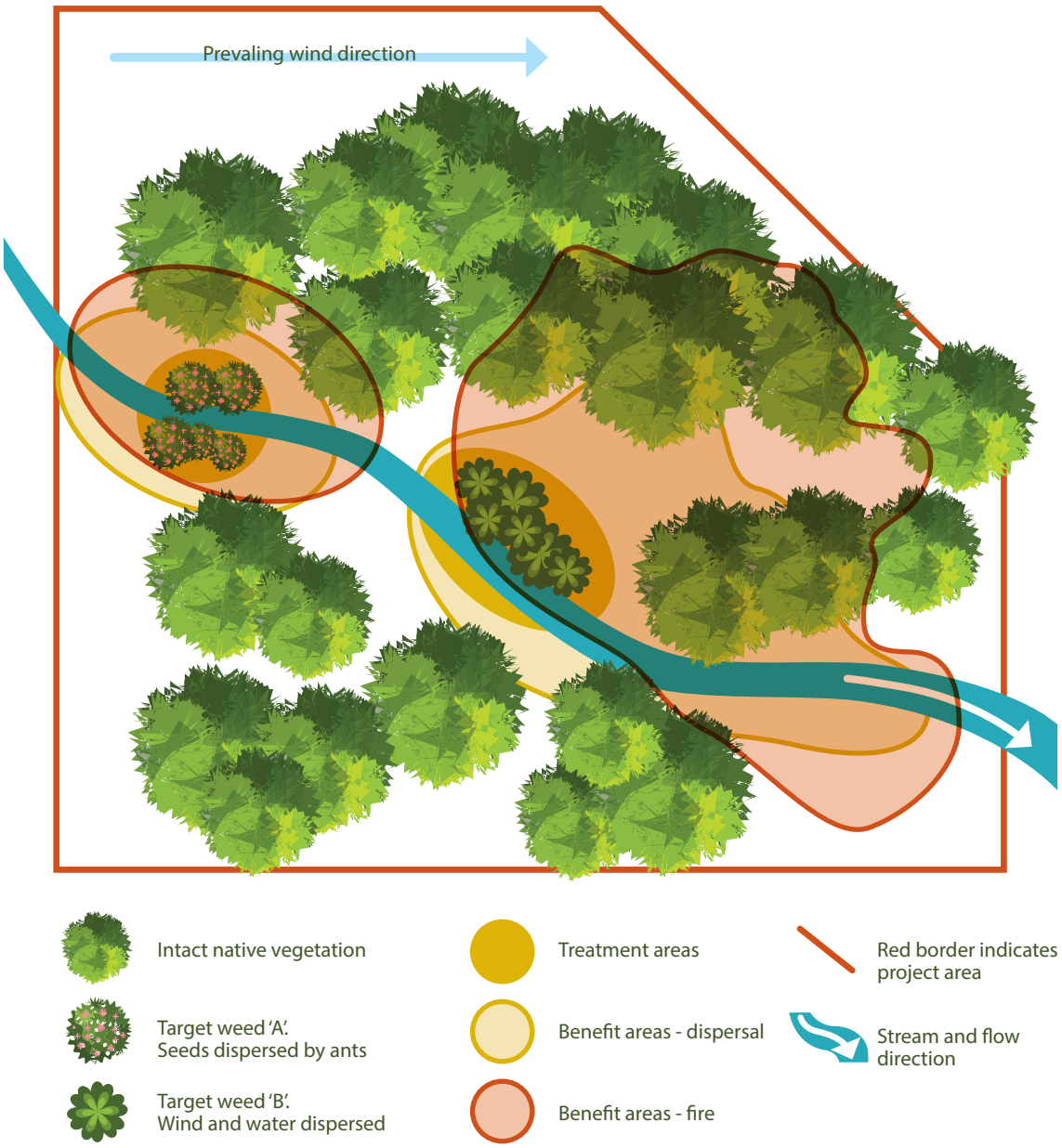


Diagram showing benefit area considering fire risk for weed species A and B.

A final assessment of the benefit area associated with controlling the two weed species may legitimately include the benefit areas associated with reducing fire risk to the native vegetation communities at the site, as well as the benefit areas associated with controlling the dispersal of weed propagules. It must be remembered that any benefit areas claimed must have a valid ecological reasoning behind the claim.

Further reading

Fitzroy Basin Weed Management Strategy, Fitzroy Basin Association, Rockhampton

Melzer, R and Plumb, J, 2007 Plants of Capricornia, Capricorn Conservation Council: Rockhampton.

Weeds in Australia, About weeds, Weeds of National Significance
http://www.environment.gov.au/biodiversity/invasive/weeds/

Weeds of South East Queensland, 3rd Edition, Weed Society Qld Brisbane.

Biosecurity Act 2014
https://www.daf.qld.gov.au/biosecurity/about-biosecurity/biosecurity-act-2014

Vehicle and machinery checklists Clean-down procedures 2014
https://www.daf.qld.gov.au/__data/assets/pdf_file/0011/58178/IPA-Cleandown-Procedures.pdf

Permit to allow minor use of an Agvet chemical product for the control of environmental weeds in non-crop areas, Permit number – PER11463
http://permits.apvma.gov.au/PER11463.PDF

Commercial operator's licence for using herbicides
https://www.business.qld.gov.au/industry/agriculture/land-management/chemical-controls/commercial-operators-licence-for-using-herbicides

Obtaining a Permit to Light Fire
https://www.ruralfire.qld.gov.au/Using_Fire_Outdoors/Pages/Obtaining-a-Permit-to-Light-Fire.aspx

Publications and Resources SEQFBC Publications
http://www.fireandbiodiversity.org.au/publications.html

Fire management guidelines
https://publications.qld.gov.au/dataset/redd/resource/c77196df-7af9-4c09-ac88-256867c39806

Problem Weeds in Calliope Shire and Gladstone, Calliope Soil Conservation Assoc. Inc. Gladstone.

Priority Weeds of the Capricorn Region. Environmental Communications, Brisbane.

What weed is that? Central Queensland. Mackay Regional Pest Management Group, Mackay.

Environmental Weeds, Class 3 Declared plants. Queensland Government, Brisbane.

Commonly Found Weeds of the Capricorn Coast. Livingstone Shire Council, Yeppoon.

Dow AgroSciences, 2004. *Woody Weed Control Guide*, Dow AgroSciences.

Queensland Department of Primary Industries and Fisheries, 2007. **Weedy Sporobolus Grasses, Best practice Manual**. Queensland Government, Brisbane.

Queensland Department of Employment, Economic Development and Innovation, 2009. *Lantana, Best Practice Manual and Decision Support Tool*, Queensland Government, Brisbane.

McNaught, I., Thackway. R., Brown,L. and Parsons, M., (2008) *A field manual for surveying and mapping nationally significant weeds*. 2nd Edition. Bureau of Rural Sciences Canberra.

Declared Weeds in Queensland
https://www.business.qld.gov.au/industry/agriculture/species/declared-pests/weeds

Erosion control

Erosion is part of a natural geological process where the action of weathering breaks down the bedrock into smaller particles.

This chapter discusses types of erosion and various erosion control techniques.

At the end of this chapter there is guidance on quantifying erosion control works for evaluation and reporting by identifying the treatment area and measuring benefit area within an ecosystem.

Image of severe gully erosion on the banks of Clyde Creek. (Source: Conservation Volunteers Australia, Gladstone)

What is erosion?

Erosion is part of a natural geological process where the action of weathering breaks down the bedrock into smaller particles. Erosion refers to both the break down and movement of these finer particles through the landscape. Wind and water are typical erosive forces; through rainfall, stream flow, waves and currents. Different substrates will have different susceptibilities to erosion.

Coupled with erosion is the complementary processes of deposition, which is the laying down of suspended particles when erosive forces are no longer sufficient to carry the particle load. Erosion and deposition are natural processes in the environment and are responsible for building up soils, creating landform features, and helping cycle minerals and nutrients through ecosystems.

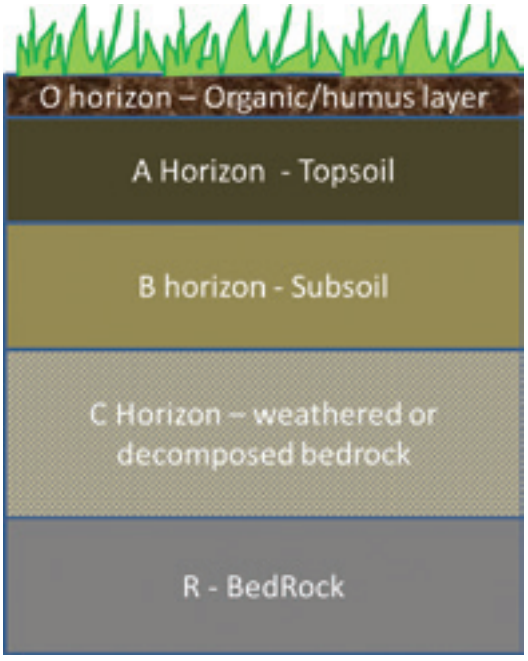
Image of an urban litter survey net choked with sediment shows the power of erosive forces. This deposit of sediment is from one storm event. (Image courtesy of CQUniversity, Gladstone)

Why control erosion?

Although erosion is a natural process, in an accelerated form it can be severely degrading to a landscape because it removes nutrient-rich surface soils, exposing infertile sub-soils and also causing downstream or downwind effects through increased deposition. According to the Fitzroy Water Quality Improvement Plan 2015, the single most important threat to the Great Barrier Reef World Heritage Area's southern section is the amount of sediment being deposited from the Fitzroy River catchment.

Erosive processes can be exacerbated by many factors including:

- excessive clearing of natural vegetation
- increased flow velocity in channels through modified natural stream processes
- increased run-off from hard surfaces
- reduction in groundcover through over-stocking, especially in sensitive areas such as wetlands, stream banks and hill slopes



Soil profile diagram. Generally Australian soils have a thin organic (O) layer and thin topsoil layer (A Horizon).

- climate change impacts, such as from prolonged droughts and more severe storms
- unsuitable agriculture techniques, for example conventional ploughing rather than minimal tillage.
- changes to soil structure and composition through physical compaction, altered chemical composition, and rising salinity
- excessive vehicle and foot traffic leading to tracks and scours.

Types of erosion

Sheet

Sheet occurs when a sheet of water moves across the land surface, taking the fine surface soil with it. Its erosive power is dependent on water volume, velocity, soil composition, slope and amount of groundcover.

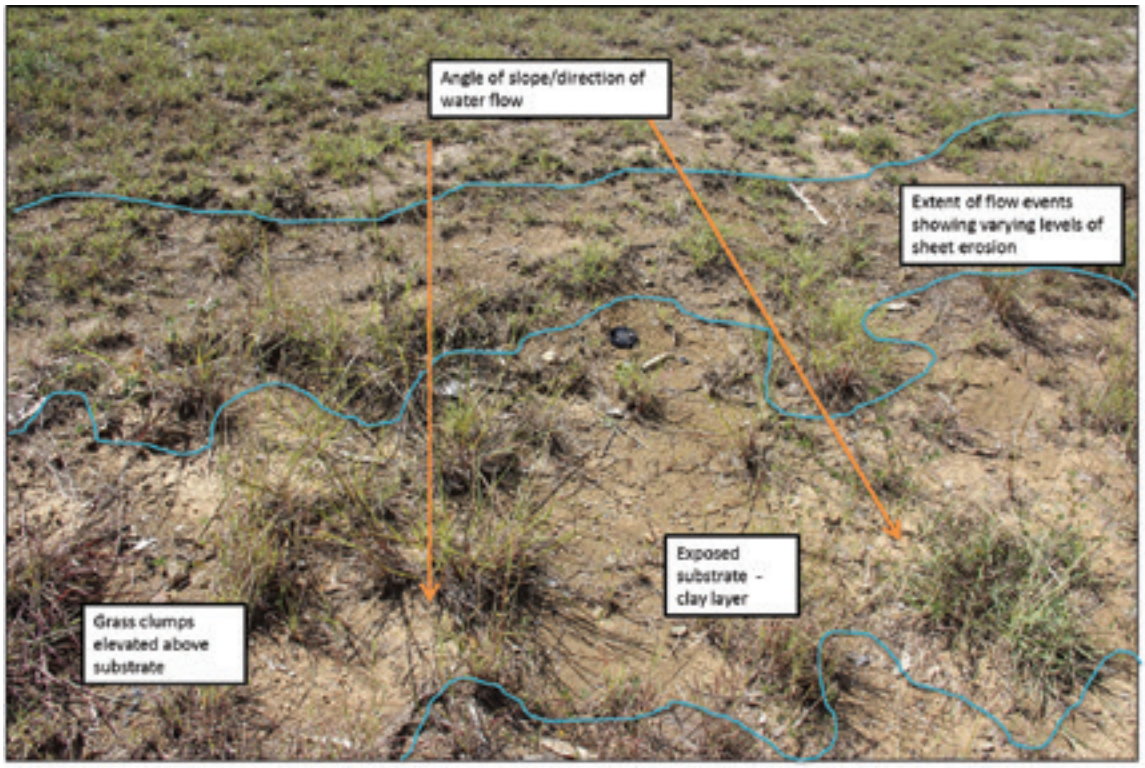


Diagram showing water flow and slope in forming sheet erosion.

> erosion is a natural process however in an accelerated form it can be severely degrading to a landscape

Rill

As erosion progresses, small channels or rills will form. These occur where the water flow follows the path of least resistance across the soil surface. As the erosion progresses, the water creates deeper channels and this, in turn, leads to increased water velocity and erosive power.

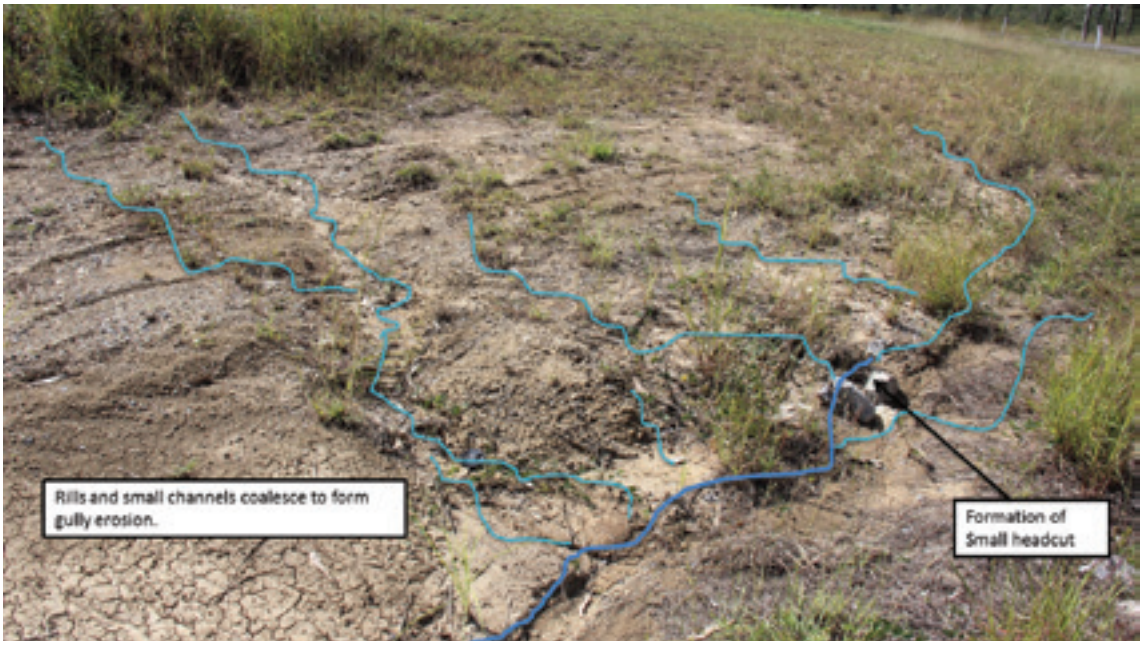


Diagram showing water flow and slope in forming rill erosion.

Gully

As rill erosion becomes more severe, eventually the water's speed and erosive capacity begins to undercut the channel edges, causing them to collapse and form wider, deeper gullies. At the upper extent of a gully, undercutting creates a 'head cut'. As water pours over this drop-off, it undermines the base and causes further collapse, often rapidly extending the gully up the slope.

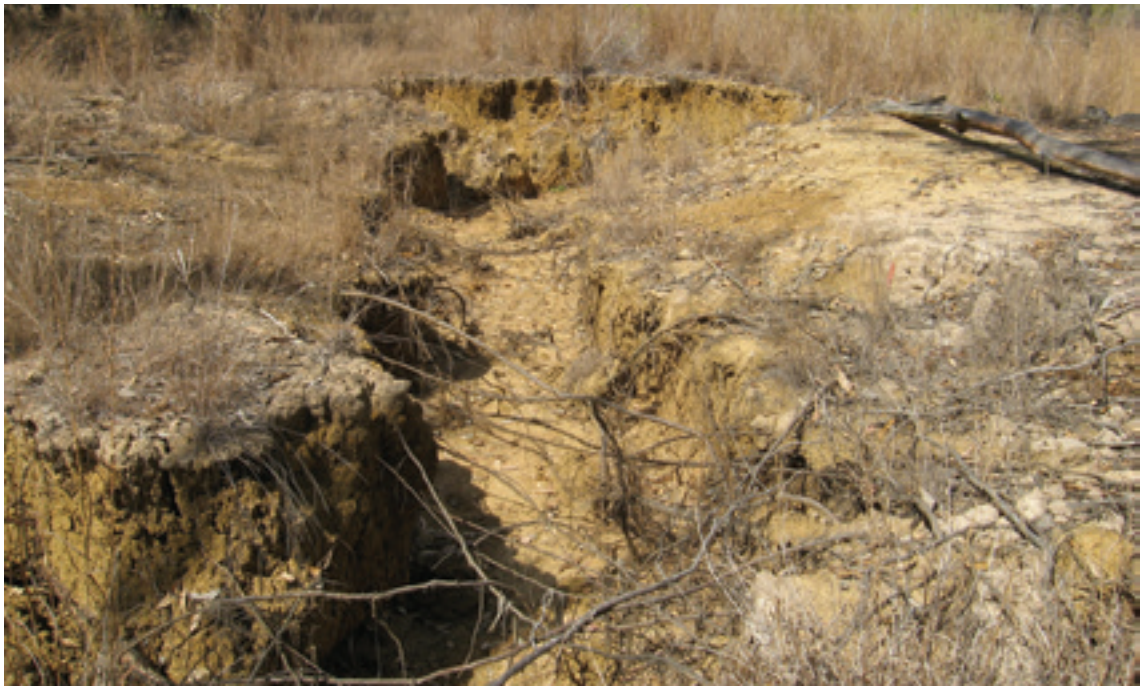


Image of degraded land heavily eroded, showing gully erosion.

Stream bank

If a waterway's bankside vegetation is degraded or absent, the stream's water flow can actively undercut the bank, causing it to slump down into the stream. During the 2011 floods, approximately 500 metres of the Fitzroy River's bank downstream of the Gavial Creek mouth slumped into the river, taking fences, roads and vegetation with it.

Diagram showing bank undercutting; creating stream bank erosion.

Coastal

The wearing away of land and the removal of beach or dune sediments by natural causes such as wave action, tidal currents, wave currents, drainage or high winds. Many erosion issues affecting coastal communities are a consequence of human-made structures or interference in the transport processes along coastlines, or reduced sand supply to the shorelines. Coastal erosion may lead to long-term losses of sediment and rocks, or the temporary redistribution of coastal sediments. Erosion in one location may result in deposition nearby.

Images of beach erosion at Putney Beach, Great Keppel Island in 2012. Left: height at high tide. Right: erosion close to buildings (Source: Lyndie Malan)

Erosion control techniques

The size and extent of an erosion problem will determine the most effective manner of rehabilitation or rectification. It is important to consider that erosion and deposition are natural processes but acceleration of these processes can have severe economic and ecological outcomes. In many instances, prevention is easier and more cost-effective than attempting to rectify a severely eroded landscape. It is vital to understand the power of a large body of moving water and the capacity for wind to move vast quantities of unconsolidated sediments such as sand, silt and fine particles.

Battering of slope

The velocity at which water moves across a soil surface determines, in part, the erosion that will occur on that surface. To reduce the surface flow velocity, altering the slope to a less-steep incline will reduce the speed of water flow and hence reduce its erosive power. Shaping the slope is termed 'battering'. The ideal batter slope will depend on the site's substrate, and expected flow velocities. Battering also helps prevent erosion undercutting steep banks and causing them to slump. Battering is usually accompanied with further erosion control methods such as seeding or using geofabrics, rock armouring or other engineering techniques.

Process

1. Experienced people carry out site assessment.
2. Plan for heavy equipment such as end loaders and excavators to access the site.
3. Grade slope according to designated plan. This is usually performed by experienced machinery operators.
4. Stabilise battered slope as soon as possible, using either geofabrics, hydromulch or seeding of a fast growing cover crop.

Tips

» Aim to minimise site disturbance especially to existing native vegetation.

» Avoid excessive soil compaction.

» Where practical, install silt traps or silt fences to prevent run-off into waterways during construction.

» Batters must be designed to minimise risk to the public.

Images of slope battering. Left: A battered slope leading into a creek crossing the Western Basin haul road, Gladstone (Image courtesy of CVA Gladstone). Right: A battered slope showing an integrated approach to erosion control: directly seeded, geofabric base layer and rock armour, Gladstone.

Stabilisation with seeds and plants

It should not come as a surprise that using vegetation is an important method of erosion control. After all, vegetation naturally holds soils together in an undisturbed landscape. Where vegetation is missing, or severely degraded, erosion is often more severe so re-establishing vegetative groundcover is a sound process for erosion control.

Process

1. Decide on species suitable for the site.
    - » Is a fast growing cover crop needed to ensure the substrate is rapidly stabilised?
    - » Are deeply rooted species needed to ensure they can withstand high flow events?
    - » Are nitrogen fixing species required due to highly degraded soil?
2. Choose a revegetation method to suit the site. For example, direct seeding, transplanting runners or stolons, using tube stock, or hydromulching.
3. If necessary, batter slopes and install geofabrics.
4. It may be necessary to install silt fences, hay bales or coir logs to trap sediments or slow overland flow.
5. Carry out chosen revegetation method.
6. Carry out follow up weeding and watering, as required.
7. Monitor site, especially after rain events, to rectify erosion issues that may arise while plants become established.

Images of stabilisation using plants and seeds. Top: Seeding a fast growing cover crop, in this case a grass, to help stabilise a bare earth bank. Note the surface has been ripped along the contour. Bottom: This creek crossing site has been battered, geofabric has been installed, the site seeded and then planted with a range of native tubestock. (Images courtesy of CVA Gladstone.)

Tips

- » Aim to minimise site disturbance, especially to existing native vegetation.
- » Where practical, install silt traps or silt fences to prevent run-off into waterways during construction.
- » Deep-stem planting may be useful in high flow areas as the plants are more firmly anchored.

Variations on technique

1. Hydromulching – is a technique where a specialised tank mix of seeds, mulch material and specialised binding agents are sprayed over exposed soil surfaces.

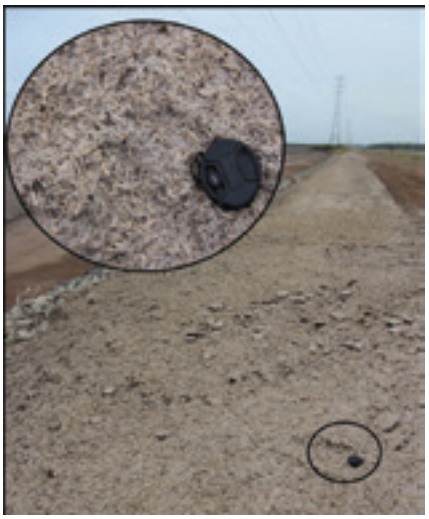


Image of hydromulching; camera lens cap included as a size reference.

Rock

In areas of higher stream flow, it may be necessary to use a substrate that is resistant to erosion. This may be achieved with rock barriers or rock beds. Rock walls are often used as coastal defences and for stabilising steep banks. Rocks can be free-standing, secured with wire mesh, or in mesh baskets — either gabions or mattresses.

Process

1. Experienced people carry out site assessment.
2. Plan for heavy equipment such as end loaders or excavators to access the site.
3. Battering of slope may be required, according to designated plan. This is usually performed by experienced machinery operators.
4. Rocks may be placed as barriers across stream flows or to deflect wave action along shorelines. Rocks may also line stream channels to prevent scouring of banks.
5. In areas of high flow, or on excessively steep slopes, wire mesh may be required to prevent rock movement.

Tips

» Rocks may be used as armour to prevent scour at the base of slopes.

» Suitably sized rocks need to be used — too small and they may scour out in high stream flow events.

» Grading rock sizes can help trap silt and fine particles.

» This technique can look unsightly and unnatural.

» Pockets of vegetation may be established among rocks to help maintain bank stability and improve aesthetics.

» Rocks can be placed inside specialised wire mesh cages (gabions or mattresses).

» Where practical, install silt traps or silt fences to prevent run-off into waterways during construction.

» Crevices among rocks may harbour vermin such as cane toads.

» Rocks may pose a safety hazard to the general public.

» Strong flows may undercut or undermine rocks, causing collapse. Placement of geofabrics or structural foundations under rockwork may be necessary.

Images of rock reinforcement in drains. Left: A stormwater drain outflow with rock armoured sidewalls, Gladstone. Right: An urban waterway using rock-filled gabions to break flow and reduce velocity, and rock-filled mattresses to prevent scouring of the bed, Gladstone.

Coconut fibre logs and hay bales

The humble hay bale can be effective for controlling erosion. It is widely used to slow down overland flow and trap sediments. In fact, it is so effective specialised fibre logs, socks and stockings are now commercially available, which use the same basic principles of the humble bale.

Process

1. Experienced people carry out site assessment.
2. Place hay bales in rows across drainage features and gullies.
3. If necessary, stake bales into the ground with hardwood stakes.

Tips

» Hay bales reduce velocity of surface water flow, but are not suited to high flow areas.

» Ensure bales are free from weed seeds.

» Where practical, use hay bales in conjunction with seeding or revegetation plantings – plantings can be shielded from flow by the bales

» Hay bales are a cost-effective and manageable technique for small to medium scale erosion issues.

» Placing bales upstream of the erosion site, where flow is less intense, can have a positive impact downstream.

» Using several rows of bales can increase the treatment's effectiveness.

Fencing

Fencing has two main uses in controlling erosion. The first method uses fencing to lessen erosive pressures on an area by excluding stock, vehicles and pedestrian traffic from sensitive erosion-prone areas, allowing natural vegetation to re-establish. The second method uses fences to trap sediments and wind-blown particles, hence reducing erosion. This method includes silt fences, which use a finely woven mesh curtain of synthetic material that restricts water flow and traps sediments, and dune fencing, which traps and stabilises wind-blown sand and in so doing builds dunes.

Process

1. Experienced people carry out site assessment.
2. Determine prevailing source of erosion – wind, water or uncontrolled access.
3. Decide on appropriate fencing method, such as stock fencing, post and rail or bollards. Consider if this fencing need to be permanent or temporary?
4. Install chosen fencing or select appropriate locations for silt or dune fencing.
5. Silt fences must sit across the path of overland flow and be securely anchored. This includes secure anchoring to the uprights, as well as to the ground. The lower edge should be buried beneath the soil surface to prevent flows from passing beneath the fence.
6. Fences can be staggered to minimise forces against any one particular fencing section.
7. Dune fences are best placed above the extent of highest tide, and at an angle to the prevailing wind. Fences should be securely anchored to the substrate and the uprights. Fences constructed of fine, woven material may need vents to alleviate the force from strong wind gusts. Dune fences may need to be fixed in a way that allows them to be moved up as sand accumulates against them.

Tips

» Aim to minimise site disturbance, especially to existing native vegetation.
» Fences may need regular maintenance to ensure they remain functional.
» Dune fences may become buried rapidly, requiring further fencing to be installed.
» Using vegetation in conjunction with fencing can improve the treatment's efficiency.
» Fencing is often the target of vandalism and regular patrols, or even security monitoring by infra-red camera, may be required.

Images of fencing. Top left: Fenced walking track to protect coastal dunes, Agnes Water. Top right: Locked vehicle access track, Gladstone. Bottom left: Silt fencing to trap sediments in surface water run-off, Western Basin haul road. Bottom right: Construction of barricades to prevent vehicle access to beach, Keppel Sands. (Images courtesy Conservation Volunteers Australia, Gladstone.)

Woody debris

A relatively simple and cost-effective method of erosion control is to use branches and other local plant material and place this in, or adjacent to, the area affected by erosion. This technique is known as brush matting. Laying the material across the direction of flow impedes water movement, slows the velocity of the water and hence reduces its capacity to carry sediments. The finer branches can trap sediments and waterborne seed and provide a stable substrate for establishing vegetation. This method can be particularly effective if the branches used are in seed, as the seeds will often become trapped and germinate in situ.

Process

1. Identify area requiring treatment.
2. Select suitably sized plant material. This may be branches pruned from local native species sourced from near the project site, and can include debris of woody weeds not in seed.
3. Place branches in deeper gullies to slow water flow. They may requiring anchoring with rocks or heavier logs.
4. Lay branches across the path of overland flow.
5. Inter-twining smaller branches can help reduce overland flow velocity, trap sediments and other waterborne debris. It can also provide a nursery microclimate for establishing native seedlings.

Tips

» Aim to minimise site disturbance, especially to existing native vegetation.

» Avoid denuding native vegetation when sourcing branches.

» Avoid using non-native species that are seeding or are known to reproduce vegetatively.

» Avoid laying large logs across channel flows as these can act as weirs. When water flows over them it can create undercuts or scouring.

» This method can be a very cost effective, locally available and easy to install for small to medium erosion problems.

» This method does not require significant engineering works.

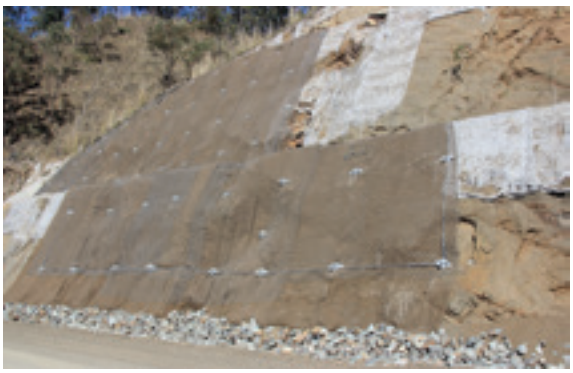
Images of using woody debris. Left: Using woody debris to reduce flow velocity, Boat Creek, Yarwun. Right: Woody debris used to minimise gully scouring Double Creek, Calliope.

Geofabrics

There are increasing numbers of specialist materials being developed to help control erosion. These include various woven fabrics of synthetic or natural fibres, plastic and steel mesh, and various socks, stockings and soil-saving devices, as well as close-weave mesh fences, gabions and mattresses for containing rock fill.

Process

1. Experienced people carry out site assessment.
2. Plan for heavy equipment such as end loaders or excavators to access the site. Rolls of geofabric can be heavy and bulky. They may require lifting equipment to place in situ.
3. Battering of slope according to designated plan. This is usually performed by experienced machinery operators.
4. Install selected geofabric as per manufacturer's instructions or best practice erosion control methodology.
5. Place additional erosion control measures as deemed necessary. This may include silt fences, hay bales or coir logs, sand bags, silt worms, seeding or hydromulching, or tubestock planting.



Tips

» Aim to minimise site disturbance, especially to existing native vegetation.

» This technique may require significant engineering works and site remediation prior to installation.

» This technique may be costly to purchase and expensive to install, but it may actually be more economical when used on a large scale. This is because extensive follow-up or remediation works may not be required.

» This method is often used for extensive areas on large scale projects.

» It may introduce unsightly elements into a natural environment.

» Plastic mesh may pose risks to wildlife.

» Geofabric must be anchored in place according to manufacturer's guidelines.

» Some natural fibres that break down over time such as jute mesh, coir logs, and natural fibre mulch mats, are available. These may be better suited to sensitive environments such as coastal sites and stream banks. They are, however, not as resilient as synthetic fibres, may require more maintenance, and alternative erosion control methods may also be needed.

Sediment traps and ponds

A sediment trap works on the principle that as water velocity slows, its ability to carry sediment will be diminished and sediment will fall out of suspension from the water column. This method is used regularly in urban sub-divisions as it is quite easy to engineer sediment traps and basins when doing groundworks on creeks and stormwater drains.

Process

1. During planning allow for the inclusion of sedimentation ponds in design. Design and construction is generally carried out by qualified contractors.
2. Sediment ponds should be wider than the natural stream, and depth should be such that water flow slows upon entering the pond.
3. Outflow from the pond should be via a spillway or a barrier should be incorporated to prevent loss of sediments downstream.
4. Heavy equipment should be able to access the pond to dredge accumulated sediments during pond maintenance activities.
5. Appropriate batters sloping into the pond should be constructed and these should be vegetated to prevent excessive run-off and erosion on the pond banks.
6. Areas of deep water and steep slopes will need adequate safety fencing.
7. Planting aquatic plants such as reeds and rushes can create a more natural-looking system, minimise bank erosion and provide habitat for wildlife.

Tip

» Bare rock walls along created wetlands tend to create habitat for cane toads, whereas reed-beds and shoreline vegetation appears to favour native frogs.

Image of sedimentation pond at Riverston Rise Estate, Boyne Island. Stormwater enters via the drain, spreads and slows dumping of its sediment load. The concrete ramp allows access for maintenance.

Signage displaying the elements of a constructed wetland designed to reduce run-off, improve water quality and assist in flood mitigation, Riverstone Rise Estate, Boyne Island.

Maintenance

Erosion control can be a costly exercise and will generally require a period of ongoing maintenance to ensure the structures remain in place during high flow events. They will also need to be checked to ensure they do not get buried in sediments, allowing water to flow over them and render them ineffective. Dune fencing will need to be checked to ensure it is not buried by sediments or damaged by king tides and wave action. Ensuring dense groundcover vegetation develops on stabilised ground is a positive action as this will help prevent further erosion. Synthetic materials may need to be removed from a site once they have outlived their usefulness as they may pose a threat to wildlife, as well as appearing unsightly and contributing to environmental pollution. Maintaining healthy groundcover is the best practice to minimise erosion.

Quantification

A project that is targeting erosion can have markedly different projects areas, treatment areas and benefit areas. While the project area may be a large area of a catchment, treatment areas may be confined to areas of severe gully or stream bank erosion. Controlling these point source origins of sediment may have benefits far downstream of the actual treatment area, and even outside the project area itself.

For example, funding may be available for reducing sediment run-off into the Great Barrier Reef. Studies show intensive grazing and clearing in the upper catchment is contributing large sediment loads to the river (the project area). Several properties along the river adopt grazing best management practices and control grazing pressure, install off-stream watering points and ensure groundcover remains above the threshold (the treatment area). The flow-on effects of this include better water quality downstream, less sediment loads entering the river, greater vegetation cover and increased biodiversity on the properties. Monitoring and evaluation shows these impacts are measurable, even outside the project area (the benefit area).

For example, in the following diagram, the project area is the landscape bordered by the red line; there is major erosion (indicated by purple degraded area) flowing into the stream. Erosion control measures initiated in the degraded area benefit the degraded area as well as downstream as indicated by the yellow benefit area. The benefit area downstream will vary depending on factors such as substrate erodibility, treatment effectiveness and the prevailing weather conditions.

Erosion and deposition can be readily measured by driving a stake into the ground and measuring the distance from the top of the stake to the soil surface. An increase in length over time indicates erosion is occurring; conversely a decrease indicates deposition is occurring.

> a project that is targeting erosion can have markedly different projects areas, treatment areas and benefit area

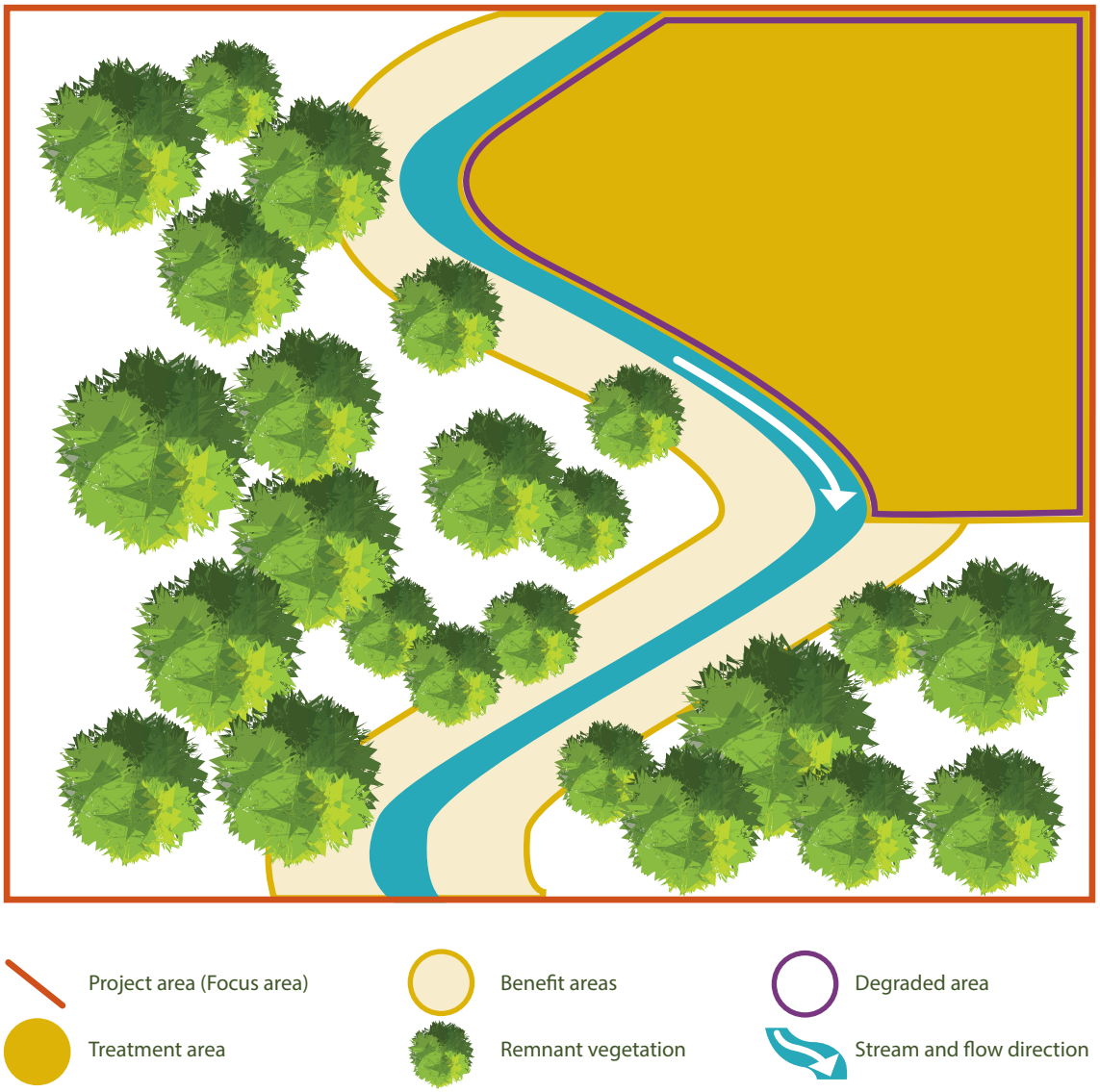


Diagram showing project area, treatment area and respective benefit areas for an erosion control project in a wet and dry season scenario.

Further reading

Fitzroy Water Quality Improvement Plan 2015
http://riverhealth.org.au/projects/fba-wqip/overview/

Clark IF and Cook BJ, 1986. *Geological Science, Perspectives of the Earth*, Australian Academy of Science, Canberra

Great Barrier Reef Marine Park Authority 2013, *Fitzroy basin assessment: Fitzroy Basin Association Natural Regional Management*, GBRMPA, Townsville.

Environmental Protection Act 1994
http://www.austlii.edu.au/au/legis/qld/consol_act/epa1994295/s440zg.html

Healthy waterways resources
http://healthywaterways.org/resources

Revegetation

Revegetation is essentially deliberately enhancing an area's vegetation through planting or regeneration. Unfortunately, excessive vegetation clearing in many parts of the region has contributed to habitat loss for plants and animals.

This chapter discusses the importance of vegetation, revegetation techniques, how to ensure successful revegetation and designing a planting plan.

At the end of this chapter there is guidance on quantifying revegetation works for evaluation and reporting; by identifying treatment area and measuring benefit area in an ecosystem.

What is revegetation?

Revegetation is essentially deliberately enhancing vegetation in an area, through planting or regeneration. The main reasons for carrying out revegetation are to:

» provide groundcover to help stabilise bare ground and restore cleared or bare land

» prevent weeds establishing

» restore and expand habitat and corridor links to isolated habitats

» restore natural processes and ecosystem functions to combat land and water degradation.

Unfortunately, excessive vegetation clearing in many parts of the region has contributed to habitat loss for plants and animals. Revegetation generally refers to establishing a vegetation community on a previously cleared site; however, this may not actually represent the site's original plant assemblage. Environmental restoration refers to rebuilding a functioning ecosystem similar to the site's original ecosystem. This may entail complete revegetation, natural regeneration or supplementary plantings to build diversity and restore the ecosystem's functionality.

Vegetation strata

An important aspect of the Regional Ecosystem framework for identifying key ecosystems is the height and density of the vegetation's tallest layer. Depending on the ecosystem, there may be several distinct layers, these layers, or strata, define the habitat. Typical layers in an ecosystem are the canopy layer, which may be dominated by tall trees; a shrub layer; occasionally a second shrub layer and finally a groundcover layer, which is often comprised of grasses, herbs or forbs. There may also be a layer of leaf litter and plant debris on the ground surface. Occasionally there are scattered emergent trees projecting above the canopy. Not all layers are represented in all ecosystems. A degraded ecosystem may not possess all representative layers or a layer may be replaced by a weed species. Multi-layering may be necessary in some ecosystems, such as Semi Evergreen Vine Thicket, to shade out competing weed species.

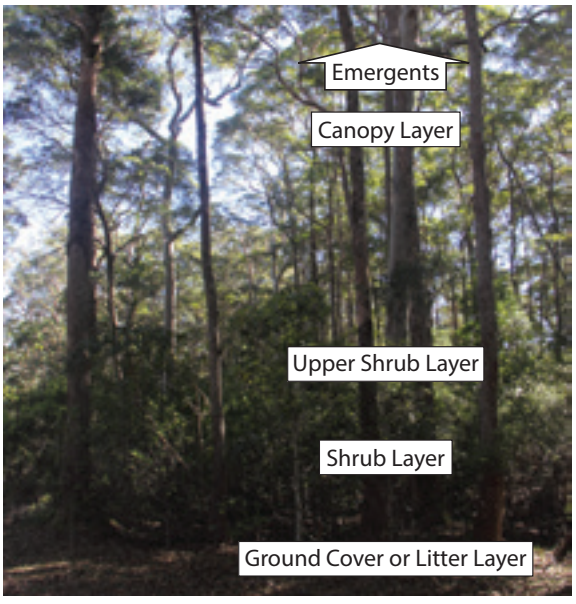


Diagram and image of vegetation strata in an open eucalypt forest, Kroombit Tops National Park.

Riparian buffer zone

A riparian zone is the vegetation that borders a waterway or lake. This vegetation is important as it helps protect the aquatic system from the direct effects of what is happening in adjacent terrestrial habitats, hence the term riparian buffer zone. Riparian buffer zones help prevent erosion, with plant

roots holding soil together, reducing flow rates and helping to mitigate against floods. They also shade and cool aquatic habitats, helping to provide habitat and cover for in-stream organisms. Importantly, riparian vegetation may trap and retain sediments and thereby help maintain water quality.

Image of riparian vegetation bordering the Mackenzie River, Central Queensland.

Vegetation and in-stream health

Vegetation shades a water body, providing dappled light to help shelter aquatic organisms from predators. Roots and fallen branches provide in-stream structure, which is used by aquatic species for shelter and habitat. Fallen leaves, fruits and other plant material may become a food source for in-stream organisms. Additionally, stream bank vegetation helps protect the bank from erosion and roots may prevent the bank from slumping. Stream bank vegetation may help maintain water quality by trapping sediments and preventing them from entering the waterway. Aquatic plants trap and bind toxic heavy metal pollutants within their tissues, removing them from solution in the water body.

Choosing the right plant for the job

An important part of any revegetation project is to select the right plant for the job at hand. While this may sound like common sense, it is often poorly done simply because the right plants are not available at the time of planting. This can be alleviated through prior planning; providing nurseries with enough lead time to grow desired species. Careful study of native species already present in the ecosystem and comparing that to species lists for similar environments in the area provides a good guide species selection.

Wherever possible, it is important to try to choose species sourced from the local area. These plants are genetically adapted to local conditions, including local climate and soil conditions and are more likely to exhibit greater survivorship. Also, by selecting local species, there is less chance of introducing the wrong species inadvertently into an ecosystem and it may also help prevent the introduction of plant diseases into new environs. It is important to plan for a project as it may take two-four years to collect a diversity of species suitable for a revegetation project.

Ecosystems undergo a natural process of change as they age and develop. The species composition and diversity will alter over time; this is termed succession. Primary succession refers to the first plants colonising bare ground, and secondary succession refers to recolonisation of plants species after a disturbance such as fire or flood. Tertiary species are those that are present in the stable, climax community that occurs in a steady state ecosystem. For the plants to establish well, it is important to select species suited to the state of environmental succession at the project site. For example, attempting to establish tertiary species in an ecosystem undergoing primary succession will probably fail as established nutrient levels, soil profiles and biodiversity factors such as pollinators are likely to be absent from a primary successional ecosystem.

Primary successional species are the early colonisers; they are generally fast-growing, short-lived species. They are also generally hardy and adaptable. Many are tolerant of poor soils and capable of fixing atmospheric nitrogen into nitrates via microbes associated with specialised structures in their roots. Often they produce large amounts of seed and are quick to germinate after disturbance.

Many tertiary species are more highly specialised species requiring particular environmental niches to develop. In many revegetation projects, selecting fast-growing colonising species characteristic of early successional stages is paramount as they often provide shelter and nutrients and create the microhabitats necessary for later successional stage vegetation to establish. It may be necessary to carry out supplementary planting of later successional species to help build diversity and improve functionality and resilience in restoration project's later stages.

Revegetation techniques

To many people, planting is the be-all and end-all of environmental restoration, as can be witnessed by high profile events such as National Tree Day. However, many mass planting events are a costly exercise in public relations, and without adequate preparation and follow-up, survivorship is often very poor. Planting native tubestock is often the most expensive way of regenerating a habitat, especially if it is done poorly, without adequate ground preparation or a designated period of follow-up treatments such as watering and weed control.

Tubestock planting

The most familiar method of revegetating an ecosystem is through using native plant tubestock. Tubestock are plants grown in specialised native tubes that are generally 50 mm square and 125 mm deep. They are designed to encourage a strong tap root to develop. Traditionally, plants are grown in a nursery until about 150–200 mm tall and then hardened off and planted out.

Process

1. Select species, allowing sufficient time to local species from a local nursery, whenever possible.
    - » Plants should be healthy and disease free.
    - » Plants should have been sun hardened prior to planting out.
2. Prepare the planting site.
    - » Remove or treat weeds to remove competition for moisture and nutrients.
    - » Cultivate soil if preparing large area. It may be easier to prepare larger areas mechanically prior to planting.
    - » Install geofabric mulch, if using. It is easier to spread mulch mechanically prior to planting. Geofabrics and mulch help retain soil moisture and supress weeds.
3. Organise all materials and tools for the planting.
4. On the day of planting, ensure tubestock are well-watered.
    - » Soaking them overnight ensures they are well-saturated.
    - » When transporting tubestock to the planting site, ensure they are kept shaded and protected from wind as this will help ensure they do not dry out.
5. If holes are dug or site cultivated prior to planting, place selected plants appropriately around the planting site.
    - » For example, riparian species adjacent to waterways and groundcover species in bare areas of established vegetation.
    - » Discard any damaged, diseased or stressed plants.
6. If holes are yet to be excavated, plants should be kept shaded and moist. Excavate holes to slightly deeper than the plant tube. If mechanical hole borers have been used, break up any shiny or polished sides of the hole and also square out the hole. Break up any large lumps of soil.
7. Add any fertilisers, soil additives or wetting agents to the hole, or mix them into the soil for backfilling the hole.
8. Use the following planting technique to minimising disturbing plant roots.
    - » Squeeze all sides of the pot to loosen the plant in the tube.
    - » Gently pinch the plant stem between the fingers of one hand and use the remainder of this hand to support the soil in the tube.
    - » Invert the pot.
    - » Tap the pot's base sharply with the other hand and gently pull the plant from the pot via the stem.

9. Place the plant into the prepared hole, ensuring the soil level in the native tube sits just below natural soil level. Do not tamper with the plant's root system.
10. Carefully backfill the planting hole, ensuring all large soil lumps are broken up and no mulch falls into the hole.
11. Use firm hand pressure to firm the soil down as you fill the hole.
12. Fill hole to normal soil level and firm down, ensuring plant is upright and firmly anchored in the soil.
13. Sculpt any excess soil into a basin around the plant to encourage water to run towards the plant.
14. Place (or replace) mulch around the plant.
    - » Ensure mulch does not contact the plant stem as it can cause fungal infection and wood rot.
15. Water in well, using a minimum of 5-10 litres of water per plant. This will help prevent air pockets in the soil, which helps prevent the roots from drying out.
16. Install any plant guards or stakes, if using.
17. Ensure all waste is cleaned up and equipment washed down.
18. Record planting efforts achieved, including date, planting conditions, species planted, area covered, and planting supplements or additives used.
19. Continue with follow-up watering until plants are established or rainfall has ensured adequate soil moisture. Maintain weed treatments to reduce competition.

Tips

- » Selecting healthy local plants from local sources can benefit survival rates.
- » Do not allow plants to dry out on planting day.
- » Select species suitable for the site.
- » Ensure plants are sun-hardened before planting out.

Images of planting. Top left: Holes drilled ready for planting. This site was partly slashed and deep-ripped to assist planting effort. Top right: Removing plant from the native tube. Bottom left: Plant installed with root mass slightly below soil surface. Bottom right: Backfilling plant, Stowe Park, Calliope. (Images courtesy Conservation Volunteers Australia, Gladstone)

Images of planting. Top left: Some basic equipment required for a planting activity. Top right: Tubestock awaiting planting. Bottom left: Selecting healthy plants and matching them to preferred site locations. Bottom right: Using a mechanised post-hole borer makes hole excavation easier, Stowe Park, Calliope. (Images courtesy Conservation Volunteers Australia, Gladstone)

Deep-stem planting

Deep-stem planting is a relatively recent innovation in planting native plant species in Australian revegetation projects. The technique uses plants that have been grown in a nursery for an extended period so they have a long stem in comparison to normal tubestock. Ideally, the plants should be grown in small native tubes but allowed to grow in such a way that the roots become air-pruned within the pot. This technique was initially successfully used for riparian revegetation projects in the New South Wales Hunter Valley, but is now being used more widely for a range of species in a variety of habitats.

Plant holes are much deeper than a usual planting hole and the plant's roots are buried deep. This allows the root ball to be deep in the soil in an area that usually retains some soil moisture. Lateral roots will form from the buried stem, anchoring the plant more firmly and help access water and nutrients from the adjacent soil. The process usually requires far less follow-up watering than normal tubestock plantings.

Process

1. Planning for deep-stem planting requires suitable lead time to ensure long-stemmed tubestock is available. It may require several months to grow suitable tubestock.
2. Select suitable planting stock for the site.
    - » Plants should have a long main stem free of side branches.
    - » Plants should be healthy and free of pests and disease.
    - » Plants should be sun-hardened prior to planting out.

3. Soak plants well prior to planting.
    - » Do not allow plants to dry out.
    - » Keep plants out of the sun and sheltered when transporting and storing on-site.
4. Prepare planting site as per the site plan.
    - » Treat weeds, control erosion, install geofabrics (if using).
5. Assemble all equipment for planting — shovels, post-hole borers, watering vessels, plant guards, stakes, and any soil additives, fertilisers or wetting agents.
    - » Ensure equipment is clean and free of weed seeds, soil, etc.
6. Holes should be dug to at least three-quarters of the plant's total depth.
    - » This may require excavating a hole at least 50 cm deep.
    - » Filling the hole with water as it is dug may help soften soil.
7. Loosen soil at sides and base of the hole, especially if 'polished' from using a post-hole borer. This helps prevent plant roots from becoming 'pot-bound' in the round hole.
8. Remove side-shoots, lateral branches and leaves up to three-quarters of the stem length.
9. Remove plant from pot, as described in tubestock plantings section.
10. Place plant in hole so the root ball is at the base of the hole and three-quarters of the plant stem is also buried in the hole.
11. Backfill around the plant, firming down as the hole is refilled.
    - » Break up large chunks of soil to prevent air pockets forming in the hole.
    - » Avoid introducing timber debris or mulch into the hole.
12. As hole is backfilled, water plant in well.
    - » This helps reduce the chances of air spaces forming and allowing roots to dry out.
13. Sculpt any remaining soil into a basin around the plant to channel water towards it.
14. Mulch and install tree guards, stakes etc. as required.
15. Carry out follow-up weed control as required.

Tips

- » Deep-stem planting requires plants to be well-established in the nursery so they have the necessary stem length to allow deep-stem planting.
- » Knowledge of plants suitable for deep-stem planting is growing. If a species is not listed, it may not have been trialled yet.
- » Due to the depth of hole required, a powered auger is useful for excavating the planting hole. Remember to square off sides and remove any soil surface polishing from the auger's action.

Images of deep stem planting. Left: Casuarina grown for deep-stem planting. Right: The excavated planting hole must be about three-quarters of the plant's height, Boat Creek, Capricorn Catchments project.

Images of deep stem planting. Top left: Inserting the plant into the planting hole, which has been half-filled with water. Note the lower leaves have been removed from the plant stem. Top right: The plant is watered in. Bottom left: Backfilling with soil. Bottom right: The end result: the plant is buried so only one quarter protrudes from the ground, Boat Creek, Yarwun.

Direct seeding

Direct seeding is a relatively cost-effective method of revegetating a site . It is often the method chosen for large-scale plantings such as mine site rehabilitation and for establishing groundcover on exposed embankments of development and roadwork sites. This method means large areas can be covered quickly, diverse species can be used, and there is no waiting period for plants to be grown in nursery facilities. There are some disadvantages, however. The soil may be susceptible to erosion until seedlings establish, and weeds may also establish and out-compete native seedlings. Seed can be costly and time consuming to collect, sort and prepare for sowing.

Process

1. Source seed from local providers, if possible.
2. Select a range of species suitable for the particular project site.
    - » If collecting own seed, understand when the particular species are in seed.
    - » Collect mature, ripe seed.
    - » Do not over-collect.
    - » Collect from a number of different trees, and from different locations, to ensure a greater degree of genetic diversity.
    - » Clean and sort seeds, and air dry them to ensure they can be stored without mould forming.
    - » Certain species must be germinated fresh and do not store well.
3. Certain seed species require special treatments prior to germination. This may include exposure to heat, exposure to a period of cold, soaking, smoke treatment or abrading the seed coat. Some species require soaking in a weak acid to simulate digestive processes.

4. Ensure site is prepared for seeding. This may require weed removal or treatment, slashing, ripping, cultivating or burning.
5. Seed can be applied in a number of ways, depending on the project's scale.
    - » Aerial seeding is used on large-scale projects.
    - » Mechanised seeding can be used on mid- to large-scale projects.
    - » Hand seeding using a hand-held lawn fertiliser spreader or simply broadcasting seed by hand can be used in smaller sites.
6. Seed may be applied in a mix with slow release fertiliser, and an inorganic filler agent (such as sand) to ensure a more even dose rate.
7. Application of seed may need to be followed with watering-in to help the seeds establish and to prevent harvesting birds or insects harvesting the seeds.
    - » Some commercially available seeds are treated with antimicrobial agents and insecticides to prevent infection and discourage ant harvesting.

Image of seed gathering from native vegetation.

Tips

- » It may be necessary to sow a groundcover crop of short-lived grasses to ensure soil is stabilised.
- » Sowing when soil moisture is high or when adequate follow-up rain is predicted may assist in germination and establishment.

Variations on technique

1. Hydromulching is a specialised technique where a tank mix containing a gluing agent, fertiliser, mulch particles and seed is sprayed onto soil surfaces such as cuttings, embankments and batters. Generally, fast-growing grass species are used to establish a binding groundcover layer; however, mixes of native species including wattles and other primary successional species may be used.

2. Seed bombing is a method of introducing later stage successional species into establishing habitats. A variety of desired seeds is rolled into a ball of clay, and slow release fertilisers may be added. This 'bomb' is then launched into inaccessible areas of habitat. As the clay ball breaks down, the seeds are released and may germinate naturally. This technique has been used to seed inaccessible areas of sites such as steep quarry faces. The technique works best when there is sufficient rainfall to dissolve the clay 'bomb' and release the seeds, as well as ensuring they germinate. Adding loam, water crystals and fertilisers to the 'bomb' may ensure a better outcome.

> revegetation is essentially deliberately enhancing an area's vegetation through planting or regeneration

Natural regeneration

Unsurprisingly, naturally regenerating a project site may, in fact, be the most effective method of environmental restoration. It can be cost effective, it relies on natural recruitment of species found in the area and requires a minimum of effort from bushland regenerators. However, it does require a commitment to control weedy species, to minimise site disturbance during weed control and restricting access to the site to let nature take its course. It lacks the high profile drawcard of revegetation events such as tree planting days and it may be some time before improvements at the site are evident. Certain species may not establish naturally if they are not represented in the immediate area.

Process

1. Identify areas of remnant habitat suitable as a source of natural regeneration materials, seeds, propagules, runners or root suckers.
2. Selectively clear weed species adjacent to these more intact areas.
3. Minimise levels of disturbance when clearing these areas.
4. Exclude entry of stock, vehicles or pedestrians from the selected regeneration areas.
5. Maintain weed control using non-invasive, minimal disturbance techniques in the regeneration areas.
6. It may be necessary to exclude fire from the regeneration plots or to actively manage fire to help naturally germinating fire-adapted species.
7. As a regenerating ecosystem develops, it can be enlarged outwards in adjoining areas.
8. It may be necessary to exclude native animals from the area as they may graze or browse newly regenerating species.

Tips

» Supplementary plantings of difficult to germinate species, or those no longer present at the site may be carried out to increase biodiversity

Figure 4.8. Left: Natural regeneration along a sediment pond, Wiggins Island, Gladstone. Right: Regeneration of melaleucas and eucalypts, Double Creek, Calliope.

Cuttings and transplants

Many plant species may grow from cuttings and many grasses will grow from stolons or runners. Using vegetative material removes the need to germinate seed and grow tubestock in a nursery. Some plant cuttings will strike readily and may be transplanted in the field; others may require a little more care and need some time in a nursery. A further method of revegetation akin to those described here is transplanting seedlings and vegetative parts of plants through root division. Plants may develop quickly with these methods. It can also be very cost effective and plants may be relocated meaning those plants growing in areas to be cleared for development are not wasted.

Process

1. Select healthy, actively growing plants free from pests and diseases.
2. Remove a suitable piece of vegetative growth using a sharp knife or secateurs.
    - » The types of cutting may vary from species to species.
    - » Grasses may regenerate from stolons or runners.
    - » Certain vines may grow from runners.
    - » Certain species require softwood cuttings to be taken.
    - » Some species require semi-hardwood cuttings — last spring's growth — to be taken.
    - » Hardwood cuttings are taken from mature (year-old) wood, and are taken with a heel from the old wood. Often, these may be directly planted into the site.
3. When taking stem cuttings, cut obliquely across the stem.
4. If transplanting cuttings, immediately dip cut ends into rooting hormone powder.
5. Excavate suitably sized hole in desired location and place cutting in the ground.
6. Firm in soil around cutting and ensure no air spaces are present in the soil.
7. Water in well.
8. Cuttings may be transferred to the nursery and potted into cutting mix.
    - » Ensure cuttings do not dry out during transport.
    - » Transport in sealed plastic bags with a little moisture and keep them cool and out of direct sunlight.
    - » Use a cutting mix: 1 part peat, 3 parts perlite, 1 part coarse vermiculite, pinch native fertiliser.
    - » Cutting mix should be open and free draining but must retain moisture.
9. It may be necessary to trim excess leaves and also re-cut the stem prior to planting into suitable pots in the nursery.
10. Maintain high humidity by watering regularly with a fine spray.
    - » Covering the cuttings with plastic bags may help maintain humidity levels around the plants.
    - » Some nurseries employ an automated misting system that sprays the cuttings regularly throughout the day.

Variations on technique

1. Seedling transplantation – may be especially useful in areas where a plant community will be lost through development. Seedlings may be transplanted from this site and moved to the restoration site. Seedlings germinated under forest canopy may also never attain maturity due to competition for light and other resources. As such, transplanting seedlings may save these specimens. Often seedlings represent a plant's genetically fittest progeny as they have germinated and grown in an area where the less fit seedlings have perished.
2. Root division – this is a method often used for propagating clumping plants such as lilies, rushes, ferns, bulbs and tussock grasses. Many clumping species tend to die down in the centre so dividing the clump may allow the plants to regenerate. Root division may involve cutting a clump into suitably sized pieces and replanting them directly into the regeneration site. In some situations, the root clumps are teased apart and the separate plants are then either planted out or allowed to re-establish in a nursery prior to being planted out. Root division works well with species such as Dianella spp. and Lomandra spp.

Images of clumps of grass being transplanted, Boyne Island Environmental Education Centre (Images courtesy Conservation Volunteers Australia, Gladstone).

> naturally regenerating a project site may, in fact, be the most effective method of environmental restoration

Recommendations for successful revegetation

Mounding

Mounding may be used in heavy soils or soils with a clay under-soil to provide for root penetration and allow water infiltration. Mounding may be used to channel water into desired locations to help create infiltration zones and to divert heavy flows away from newly revegetated areas. Building mounds on the soil surface may also help avoid salt-laden and infertile subsoils. Planting salt-tolerant species in the furrows between mounds has been effective at lowering a saline water table and allowing less salt-tolerant species to establish on mounds.

Ripping

Ripping is used to increase water percolation and root penetration in heavy soils. It may also help aerate the soil and allow weathering to act on it to help break up heavy compaction and hard crusts. Ripping can also loosen soils to aid in digging when doing mass plantings. Ripping may be used to introduce chemicals and fertilisers into the soil. Spreading top soil, lime or fertiliser on the soil and ripping it, allows it to be readily mixed into less fertile or leached soils, thus improving soil quality. Care must be taken in areas with low soil oxygen content such as wetland areas, mangrove and tidal plains as exposure of sub-soils to the atmosphere may release acid sulfates, creating low pH, which can adversely affect water quality.

Image of ripping of site to facilitate water percolation and ease of planting, Stowe Park, Calliope (Image courtesy Conservation Volunteers Australia, Gladstone)

Topsoil

Adding topsoil can reintroduce a soil layer possibly missing through erosion. It also may reintroduce an organic soil component lacking in poor soils. Good quality topsoil can add nutrients and soil organisms to a site, improving soil quality and also providing a suitable anchoring medium for plants. Ripping combined with topsoil addition may help combine the soil layers, aerate the ground and break up any hard crusts that may act as a barrier to water infiltration or root penetration. Topsoil may need to be certified as being clean and free from weed seeds or vegetative plant material.

Image of volunteers spread well-rotted mulch to provide topsoil on a roadside batter, Kirkwood Road, Gladstone. (Image courtesy Conservation Volunteers Australia, Gladstone)

Fertiliser

Most Australian natives do not tolerate large quantities of fertiliser. Specific slow-release, low-phosphorus native fertilisers may, however, be useful in nutrient deficient environs, such as foredunes or heavily eroded or badly leached sites, to provide nutrients and trace elements in early stages of growth.

Water crystals

Water crystals are additives designed to hold water in the soil adjacent to plant roots. There are a number of types available, the most common is a crystalline product that is highly hygroscopic and will absorb many times its weight in water, forming a jelly-like substance. This can be mixed into the soil when planting to help retain soil moisture.

Soil wetting agents

Soil wetting agents are special detergent-like solutions designed to help break the soil's natural water repellence and allow greater absorption of water. In areas with infrequent rainfall and high evaporation, these additives may be useful to augment the soil's capacity to absorb and retain moisture and ensure a greater chance of plant survival.

Mulch

Mulch is a layer of usually organic material placed around a plant. Common mulches include hay, straw and cane trash, grass clippings, pine bark and wood chip. There are also some manufactured mulch matting materials available including jute and fibre mesh. Natural mulch materials may contain weed seeds and sourcing mulch certified weed-free may be necessary.

Mulch helps retain moisture in the soil adjacent to the plant. It shades the ground surface, keeping it cooler, and also reduces evaporative water loss. Mulch can add an organic layer to the soil, add nutrients and encourage soil fauna, bacteria and fungi. Action of soil organisms can enrich the soil and also aerate it, allowing greater water penetration. Increased organic material in a soil can help retain moisture.

Mulch also plays a major role in suppressing weed growth, and can be useful for delineating a site. A well-mulched planting site not only looks good but may also be easier to manage.

Images of mulching. Left: Using biscuits of hay to mulch around plantings, Stowe Park, Calliope. Right: Mulching a National Tree Day site, South Trees, Boyne Island. (Image courtesy Conservation Volunteers Australia, Gladstone)

Weed control

Controlling weeds is an important part of any planting project, as weeds will compete with desired plants for space, light, water and nutrients. Weeds are often faster growing and more efficient colonisers of disturbed ground than native species. Removing weeds stops them from smothering the planting site. Clearing weeds from around desired species may help prevent them from being mown or slashed off as the new plants may be more visible.

Image of brushcutting weeds around a planting site to reduce competition for resources. (Image courtesy Conservation Volunteers Australia, Gladstone)

Animal control

Occasionally it may be necessary to exclude animals that may graze on or physically damage the planting on the project site. Species such as certain wallabies, especially black-striped wallabies, rabbits, hares and stock such as cows, goats and deer may significantly damage newly planted vegetation. It may be necessary to exclude larger species from the area using suitable fencing, or plant guards. In cases where damage from introduced pest species is excessive, it may be necessary to carry out baiting or culling.

Tree guards and stakes

There are various styles and materials used for tree guards. Some may be wire mesh that simply prevents grazing on the plant, others are made of plastics or stout, waxed card. These may be employed, not only as plant protection from grazing, but also to reduce desiccation from the action of wind and sun. Plant guards may also create a microclimate around the plant, retaining moisture, increasing humidity and causing any evaporation or transpiration to be returned to the soil adjacent to the plant.

Plant guards are useful for identifying a planting site, and may help prevent plants being mown if weeds grow up around them. They also offer a visual stimulus to show that works have been carried out in an area, which can be important for publicising the restoration project's progress and maintaining motivation among bush regenerators working on a project site.

Images of tree guards and stakes. Top left: Plastic bag tree guards and mulch mats, Canoe Point. (Image courtesy Conservation Volunteers Australia, Gladstone) Top right and bottom left: Corflute tree guards, Boat Creek. Bottom right: Threading the stakes through a plastic tree guard can help prevent it becoming dislodged, Nagoorin, Boyne Valley.

Soft, plastic-bag-style plant tubes may collapse, especially if they are not well-staked. If they fall over the plant, they may cause it to overheat. They also add to plastic debris in the environment if not staked down well and they be carried off in floods or strong winds. Waxed, milk-carton-type material or corflute-type guards, while more expensive, are less likely to have these issues and may be used multiple times. Some plant guards are also designed with water reservoirs in the plastic layer, to facilitate applying water slowly to the new plantings.

Watering regime

Follow-up watering at a planting site is often neglected. Obviously, the need to carry out follow-up watering will depend on the species selected, the site, its location and the prevailing weather around the planting event. The planting method employed, use of mulch, water crystals and the initial watering will also play a major part in determining the follow-up watering regime.

In most instances, a good soaking is better than a light watering as it allows good water penetration and encourages a strong, deep root system to develop. Light watering generally only encourages surface root production and as this surface soil profile dries out rapidly, plants can quickly submit to water stress.

Watering regimes will be dependent on soil type, composition, prevailing weather conditions and shelter of the site. Using mulch, water crystals and increased humus in soils can also help maintain soil moisture after watering. Monitoring the site after planting, and proactively watering when plants appear water-stressed, is probably the best means of assuring greater planting success. This again highlights the importance of project planning, flexibility in the planning and allowing for project follow-up.

Images of follow-up watering. Left: Follow-up watering at a planting site, Kirkwood Road, Gladstone. Right: Watered and re-mulched planting. (Images courtesy Conservation Volunteers Australia, Gladstone)

Timing of works

Consensus in Central Queensland indicates the ideal planting period is while soil moisture remains high after the summer wet season and before the cooler, drier months of winter. If plantings are carried out in cooler months (autumn to winter) new plants have time to establish and develop their root systems over the winter months, ready to flush with new growth after spring rains. Planting at this time avoids the summer heat and may also avoid the flood events associated with strong summer rains if carrying out riparian plantings. Plantings may need to be carried out at other times of the year, dependant on project timelines, site and environmental constraints and also species availability. These works may be successful but may also require more intensive follow-up and management.

Considerations

Soil types

Australia is generally characterised by poor, nutrient-deficient soils. Soils may be heavily leached of nutrients or heavily laden with mineral salts and leading to high salinity. In areas where revegetation is likely to be required, topsoils are often lacking or the soil profile may be disturbed.

Some plants species, particularly legumes, have the ability to fix atmospheric nitrogen into nitrates via structures housing microbes on their root systems. This ability is known as 'nitrogen fixing' and allows the plants to generate their own fertiliser, so to speak. Planting a primary nitrogen-fixing species, such as *Acacia* or *Casuarina* species, can help improve poor soils by adding nitrogen and humus to the soil. These species may also create sheltered microhabitats, allowing other plant species to germinate.

Where the substrate is heavily degraded, leached of nutrients, deficient in humus or lacking in soil fauna, it may be necessary to add supplements to the soil to ensure plantings will establish. For example, adding potting mix or coir peat, fertiliser and water crystals to the soil when planting beach scrub species into degraded hind dunes can improve success. A good handful of a quality potting mix can help introduce soil microbes to the relatively sterile and nutrient-poor sand, and also add humus, which may help retain moisture around the plant's root ball. Protection from sun and wind using plant guards or dune fences may also be required.

Images of degraded soil. Left: A highly degraded slope with no topsoil, Winery Hill, Gladstone. Right: A highly compacted surface layer, Western Basin Haul Road, Gladstone. (Images courtesy Conservation Volunteers Australia, Gladstone)

Where soils are relatively intact, it may be possible to plant directly into well-prepared local soil. Removing large lumps, rocks and plant roots from the soil can ensure no air spaces remain when the soil is firmed down around a new plant. Adding water crystals or a soil wetting agent can benefit where rainfall is erratic.

A slow-release fertiliser designed for native species may be used; however, many Australian natives do not tolerate high levels of fertiliser.

Intertidal zones

Typically, tidal environments are harsh with elevated salinity levels; poor, heavy soils and high exposure to sun and wind. It is important to select hardy salt-tolerant species for planting. In these environments, transplanting clumps of salt-tolerant vegetation has been trialled successfully. Plantings should be well-anchored and watered in well.

Image of salt-tolerant species transplanted alongside an urban estuary, Gladstone.

Riparian zones with risk of high-flow flash flooding

Riparian planting sites will require careful selection of species. Ideal species will be fast-growing with a well-developed matting root system that will bind the soil and anchor the plant during flood events. Plantings should be concentrated in areas of lower flow, such as in the shelter of snags and on the inner banks of bends where flow is reduced. It may even be beneficial to retain weed species if they are holding sediments and reducing flow rate, then gradually introduce native species from areas of least disturbance. Plantings should occur after the likelihood of large flow events to allow sufficient time for the new plants to establish. The deep-stem planting technique is especially suited to this situation as the plant is well-anchored in the ground and capable of withstanding flow events.

Image of deep-stem planting site at Boat Creek, Yarwun, after a mid-range flow event. Plants are still well-bedded in.

Steep slope, severe erosion with no topsoil

Establishing plantings on steep slopes is a difficult proposition, as erosion is likely to have removed the topsoil and leached nutrients from the site. In this situation, it is important to attempt to divert water flow away from the planting site, batter the slope to a less severe angle to slow the water flow and install geofabrics, coir logs or hay bales to create pockets that will trap sediments and retain soils. Adding topsoils and fertiliser may be necessary.

Choosing fast-growing species that can help bind soil and those that can fix atmospheric nitrogen may be beneficial to the planting's success.

Riparian planting sites will require careful selection of species

Designing a planting plan

Strip planting

Strip planting refers to long, narrow plantings such as are often carried out on riverbanks, shorelines and also as shelterbelts and buffer zones along road and rail corridors. Strip plantings can create vegetation corridors to link patches of remnant habitat. They are ideal for riparian and coastal plantings as they can recreate zones corresponding to the influence of moisture, shelter, salinity and so forth. In urban plantings, strip planting along riparian zones can provide wildlife with corridors through built-up areas and can also help waterway management. By using strip planting along the banks of watercourses, in-stream benefits such as shading, presence of snags and habitat is increased, flow is regulated and sediments are trapped. Developing a healthy riparian zone on steep or hard to access stream banks may alleviate risks associated with mowing or slashing. A disadvantage of strip plantings is that long, narrow belts are more prone to edge effects: impacts from fire and weed encroachment along the edges of the strip. It may be necessary to create buffer zones of other vegetation adjacent to strip plantings and maintain a higher degree of maintenance to ensure weed impacts are minimised.

Image of strip planting along a powerline easement. (Image courtesy Conservation Volunteers Australia, Gladstone)

Island planting

Island planting involves planting native vegetation in distinct clumps. This method is particularly suited to areas with some remnant vegetation present as the plantings can augment and link isolated patches. Planting in clumps can be easier to mulch, water and treat weeds within the clump and still allow easy access for mowing or slashing around the plantings. It is possible to group similar species together and create specific types of microhabitats that encourages particular species, or to emulate a specific habitat type. This can create interesting features for urban plantings. An advantage of island plantings is that it can allow access to interstitial areas for management such as slashing, mowing and weed control, until works can progress to link up the separate plantings.

Image of island planting between isolated trees, Double Creek, Calliope.

Companion planting

Companion planting refers to the requirement of certain species to be planted together to ensure they both grow and thrive. Companion planting can provide microhabitats for less hardy species, they may be used to condition soil, provide shelter, add humus or deter insect pests. Some Australian plants are root parasites and require a host plant to develop. Others, such as strangler figs, benefit from the support of other trees. Often the fig seedling grows among branches high in a host tree, allowing it to gather more sunlight. Its nutrient needs are provided by decaying leaves until it is able to send its roots to the ground. Eventually the fig tree may strangle its host tree and killing it.

Quantification

A planting project is often only carried out on a small part of a project site because of the cost and work involved. Many natural resource management agencies are steering away from mass plantings as they are costly and follow-up is often lacking, meaning survival rates are often low. Increasingly, planting events are smaller and the emphasis is on obtaining a high survivorship through more careful planting and better follow-up. As such, a treatment area may only be a small part of a much larger project site. There can be multiple benefits from such a regeneration project. The treatment might encourage new wildlife species to use the area, it may trap sediments, lessen erosion and perhaps link areas of disconnected habitat. It is vital to consider the ecological impacts of any treatments that are carried out on a project site, as the benefits may be far-reaching.

In the example below, patches of remnant vegetation are isolated from one another. Isolation and small patch size can make remnant vegetation more vulnerable to degradation, as well as make it difficult for animals to move through the landscape. By enlarging one patch and planting a new area between, landscape connectivity is improved and the health of remnants and new plantings can be strengthened. In addition, plantings close to waterways can help stabilise the system, reducing erosion and facilitating the process of natural regeneration.

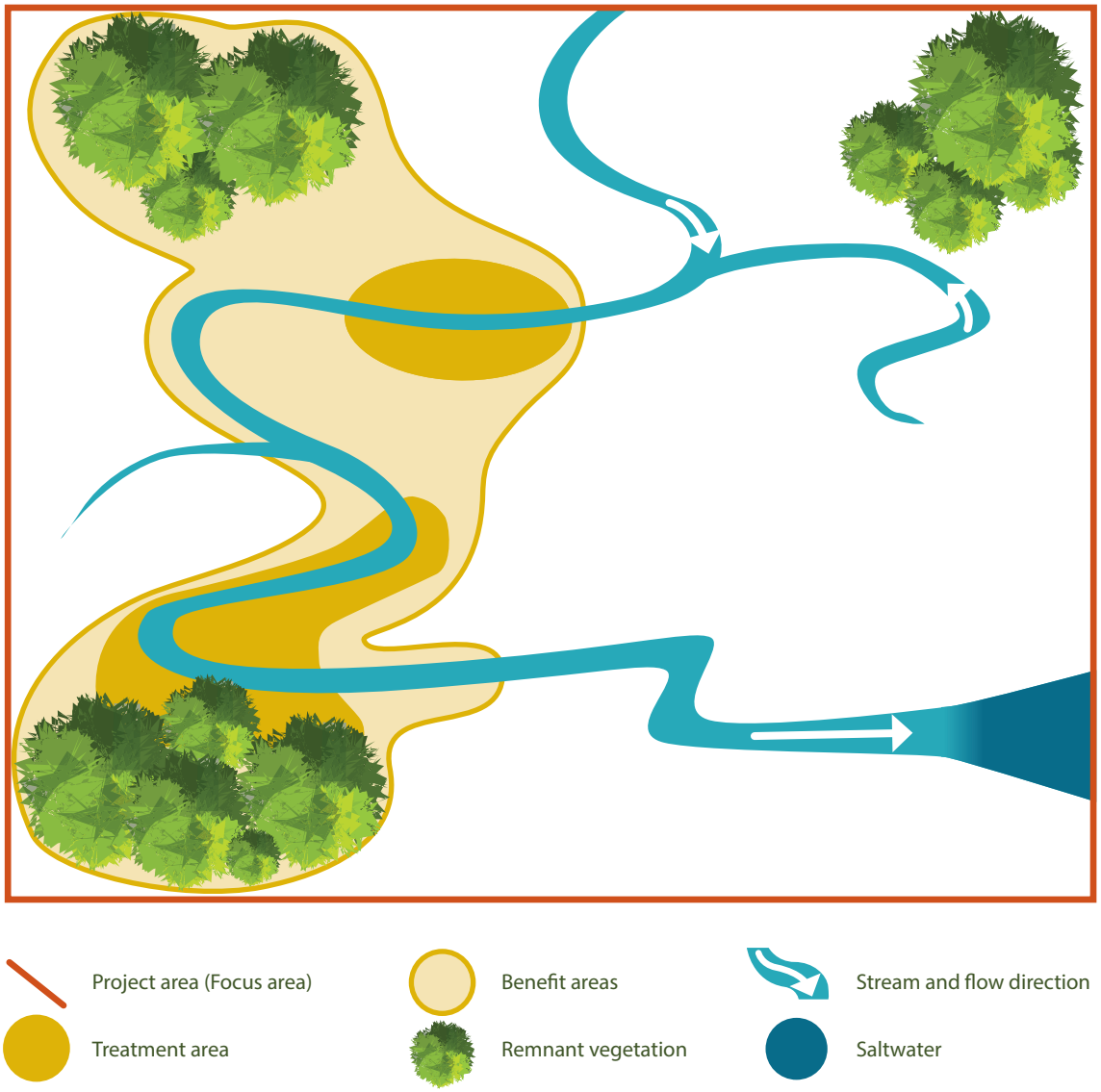


Diagram showing multiple benefits associated with revegetation.

Further reading

The Long-Stem Planting Guide Gosford City Council
http://www.environment.nsw.gov.au/resources/grants/Longstemguide.pdf

Long Stem Planting Fact Sheet 28
http://www.australianplants.org/fsztwentyeight.htm

> environmental restoration refers to rebuilding a functioning ecosystem similar to the site's original ecosystem

Litter reduction

Litter is unwanted or undesirable material or substances that have been disposed of improperly, without consent, at an inappropriate location. Litter can be intentionally, accidentally or unintentionally disposed of. Litter is unsightly, unhealthy, damages the environment, contributes to pollution, and harms wildlife; it is also costly to clean up.

This chapter discusses types of litter, litter survey techniques and litter reduction techniques.

At the end of this chapter there is guidance on quantifying litter reduction works for evaluation and reporting; by identifying treatment area and measuring benefit area in an ecosystem.

What is litter?

Litter is unwanted or undesirable material or substances that have been disposed of improperly, without consent, at an inappropriate location. Litter can be intentionally, accidentally or unintentionally disposed of. Litter is unsightly, unhealthy, damages the environment, contributes to pollution, and harms wildlife; it is also costly to clean up.

The Beverage Industry Environmental Council Littering Behaviour Study 2004 identified common reasons why people litter:

» Unaware - Littering is not always a deliberate act and may result from uncertainty as to who is responsible for disposal. Alternatively, littering may be viewed as an inconsequential thing to do. For instance, householders and businesses may dump at the front of their property, thinking it is the council's responsibility to clean it up.

» Careless - Some people litter because it is too much trouble for them to do otherwise, or litter is something they simply do not think about. Convenience is often the driving factor here, hence well-located and designed disposal units and bins have a good chance of improving behaviours.

» Premeditated - Individuals may be well aware that littering and dumping are illegal, but find it more convenient (and cheaper if not caught) to find a hidden dumping spot, or simply dispose of smaller litter items irresponsibly. Here, the thinking is that they are unlikely to be caught or shamed. Enforcement and education play a primary role in improving these behaviours.

The *Environmental Protection Act 1994* outlines littering legislation in Queensland and local governments also enforce littering legislation under local laws. The Department of Environment and Heritage Protection's Littering and Illegal Dumping Online Reporting System (LIDORS) allows members of the public who have witnessed a littering or illegal dumping incident to report it to the department.

The Keep Australia Beautiful National Litter Index is an annual quantitative study of the volume and type of litter found across Australia. The National Litter Index categorises site locations, litter types and volumes. It is possible to use the National Litter Index as a benchmark and compare results with the national baseline to determine trends and identify where improvements can be made.

The Australian Marine Debris Database was created to enable volunteers and organisations running beach clean-up events to also collect data on what they were finding with a consistent methodology. This allows it to be collated into a standardised national database on marine debris.

Urban rubbish

Possibly one of the most prevalent rubbish issues in and around urban centres is littering and illegal dumping. Despite annual clean-up days and other large-scale, high-profile litter clean-up events, the amount of illegally dumped rubbish seems to continually increase. Increasing population, a greater percentage of 'disposable' goods, extensive use of non-biodegradable materials and high waste disposal fees are possibly to blame.

Images of urban litter. Top left: Illegal urban dumping in a wetland area north of Gladstone. Top right and bottom left: Dumping in bushland adjacent to wetlands in South Gladstone. Bottom right: Glass collected from marine plain near Gladstone. (Top right, bottom left and bottom right images courtesy Conservation Volunteers Australia, Gladstone)

> Despite annual clean-up days the amount of illegally dumped rubbish seems to continually increase

Urban water run-off

The combination of hard surfaces, lack of opportunity for infiltration, and channelling of water within urban areas alters natural stream flows. Instead of a steady flow, flows tend to be pulsed, high energy and often laden with debris, litter and chemicals, oils and greases from roadways, industrial outflows and factory or workshop drains.

Images of urban drains. Left: Urban drain showing hard surfaces and loss of natural stream attributes. Right: Urban drain designed with rock-filled gabions to reduce flow velocity but note lack of bank-side vegetation and uniform sides, Gladstone.

Images of industry debris. Top left: Industrial wastewater run-off containing oil, which contaminated saltwater wetlands, Wapentake Gladstone. Top right: Oiled kingfisher, Wapentake Wetlands, Gladstone. (Images courtesy Conservation Volunteers Australia, Gladstone) Bottom left and bottom right: Grease balls contaminating foreshores at Fishermans Landing, Gladstone. This grease probably came from the servicing of dredging equipment being used in Gladstone Harbour. (Images courtesy CQUniversity, Gladstone)

In a natural environment, vegetation slows overland flow and helps trap sediments and debris, including litter. As the overland flow in a natural system has more time in contact with the substrate, it can overcome the soil's initial water repellent nature, allowing water to percolate into the soil. The soil then absorbs some of this flow, reducing flow volume and also helping to filter debris from the

water. Soil microorganisms may then have a chance to act upon chemicals in the run-off and break them down or bind them into more inert molecules. Note: this is entirely dependent on the nature of the chemicals involved and time elapsed between exposure to those chemicals. Likewise, reactions may occur in soils to immobilise certain chemicals. For example, clay soils may bind some chemical residues into non-reactive compounds.

Images of stormwater drains and debris. Top left: Urban drain in flood. Top right: CQUniversity researchers check a stormwater debris monitoring net. Bottom left: Debris accumulates in a creek system after a flow event. Bottom right: A stormwater debris net traps a large amount of litter, in central Gladstone. (Top left, top right and bottom right images courtesy CQUniversity, Gladstone Environmental Centre. Bottom left image courtesy Conservation Volunteers Australia, Gladstone).

Marine debris

Perhaps unsurprisingly, large amounts of non-biodegradable materials — especially plastics — end up in the marine environment. A significant percentage of this material, possibly up to 80 per cent is land-sourced debris entering the marine environment via urban drains, feeding into coastal rivers and creeks. In remote areas, sea-based debris is brought in on ocean currents from other countries, recreational boats, fisheries or cargo ships, where it is either washed overboard or intentionally dumped into the ocean.

Ocean currents tend to concentrate this plastic material and it will either remain in suspension in the water column, become deposited in the ocean sediments or be returned to the coast and deposited back on land. High storm tides and wave action can resuspene or return marine debris back to the water column. Due to its longevity in the environment, it may persist for decades and repeat this cycle many times over.

Marine debris is listed as a key threatening process under the EPBC Act due to the harm it causes to marine life. Marine debris in the form of discarded fishing line and nets, and nylon ropes and cords all pose an entanglement risk for marine animals. Discarded nets, especially made with monofilament nylon, may continue fishing indiscriminately for years and are termed 'ghost nets'. Plastic bags may be mistaken as prey by marine life and when swallowed may block the digestive tract and cause death through starvation. When the dead animal decays, the plastic may be released, posing a threat once more.

Although public perception is largely focussed on the larger, more iconic marine life impacted by marine debris, such as dolphins, turtles, whales, seals and seabirds, the impacts on smaller species are largely neglected. With plastics comprising a greater percentage of plankton trawl captures than marine plankton in certain parts of the Pacific, and entire layers of sediments dominated by micro-plastics, the likely impact on other species, including commercially important species, may be significantly high. Plastics can also bind toxins to their surface and are often highly toxic in their composition and certain toxic compounds may accumulate through the food chain.

Above: Images of marine debris. Left: Items of marine debris collected during a survey of Peak Island, Keppel Bay. Right: Marine debris accumulation on northern Curtis Island's ocean beach. (Image courtesy CQUniversity, Gladstone).

Above: Images of monofilament net found washed on turtle nesting beach, Facing Island.

Litter surveying techniques

Marine debris survey

Suitable beaches and foreshore areas are identified from aerial photographs, maps and water circulation models, if available. This is find depositional beaches: areas where wind, tides and currents tend to deposit marine debris. Select survey sites at north, central and southern ends of a beach or alternatively areas of high use, or areas rarely visited.

Each survey site should be large enough to accommodate at least three 50 metre transects running parallel to the water, with a minimum of 10 metres gap between each. Sites should be selected for uniformity. Do not select sites obstructed by offshore reefs or adjacent to headlands as these will alter deposition rates and patterns.

Map showing how to establish marine debris survey sites for a coastal beach.

Once sites are established they must be suitably marked, either with permanent marker posts above the reach of tides or by GPS. This enables the sites to be revisited for gathering seasonal data. Surveys can be performed in a 20 m wide belt along the transect line (10 m either side of the transect line) at the level of the last high tide, or alternatively from the level of the first dune to the waterline. If this, or a suitable alternative, survey method is chosen, this must remain consistent for all subsequent site surveys.

Depending on the size of the clean-up activity or amount of marine debris on site, ensure there is an appropriate plan for the collected debris. Contact the local council to pre-arrange collection or disposal of marine debris.

Images of marine debris surveying. Left: Volunteers survey debris along a 50 m transect at the high water mark. Middle: Conservation Volunteers Australia volunteers scour the high water mark at Facing Island for marine debris. Right: Researcher Dr Scott Wilson examines an item of marine debris. (Images courtesy Conservation Volunteers Australia, Gladstone)

Process (adapted from Tangaroa Blue's 'How to run a beach clean-up' instructions)

1. Hold a safety briefing for all staff and volunteers. Ensure volunteer insurance is organised and appropriate paperwork has been completed. Volunteers under the age of 18 should be accompanied by an adult.
2. Delegate clean-up areas informing volunteers of any hazards, time-frames or other additional information. Distribute clean-up materials to volunteers. Ensure volunteers work in pairs or groups, and not alone.
3. Ensure all volunteers have appropriate safety equipment including gloves, shoes, sunscreen, drinking water, sunglasses and eye protection and appropriate clothing. Ensure there are hand-washing facilities or antiseptic hand wipes available.
4. Ensure there is at least one volunteer who knows how to handle syringes.
5. If you find abandoned cars, weapons or suspicious items, contact the local police immediately.
6. Let volunteers know what to collect during the clean-up, that is all human-made materials.
7. At the end of the clean-up, empty the bags onto a tarp and sort into item groups (see the data collection sheet in Appendix C) and weigh collected debris. Separate materials that can be recycled and dispose of appropriately. Alternatively, complete data collection sheets at the time of placing rubbish into bags while on site and sort and recycle after.
8. Any unlisted items can be written under the data collection sheet's "additional Items" section and any item that cannot be identified can be photographed and also submitted.
9. Return completed data collection sheet to Tangaroa Blue or submit data online to the Australian Marine Debris Database along with any photos, reports and media coverage.
10. Make sure there is a plan for disposing the collected rubbish.

Tips

» Submit data collection sheets to the Australian Marine Debris Initiative Tangaroa Blue Australian Marine Debris Database as well as retaining for site surveying.

» Collecting data at the time of collecting debris is much more time-efficient than completing the data collection after the clean-up; however, inexperience using the sheet can lead to inaccurate data and holds up the clean-up stage. Be familiar with the data collection sheet and print the sheet in a fashion that suits field use.

» Please be environmentally sensitive — some clean-up sites may include nesting areas for endangered birds or have Aboriginal historical sites — please keep clear of these areas. Contact the local Department of Indigenous Affairs and Department of Environment for further information.

Urban rubbish

Urban rubbish surveys may comprise a transect method similar to that described for marine debris with transects running parallel to creeks or waterways or a discharge point source method for calculating urban rubbish being deposited into the marine environment via stormwater drains. The Tangaroa Blue Marine Debris data sheet can be used as a data collection tool, and it is possible to modify this sheet to collect particular information about rubbish collected, that is, the source of particular items from nearby stores.

The point source method is usually only carried out after a significant rain event (15–20 mm) and involves placing temporary mesh screens or nets over selected stormwater outflows. Different sized nets may be used to sample different size classes of debris. Council schematic plans can show which drains service which areas, so can give an estimate of the size area sampled. Flow rates may be calculated to give a value of weight of debris per volume sampled. Data can be recorded on similar data sheets to those used for marine debris sampling.

Image of point source debris sampling trap over a central Gladstone stormwater drain outflow. This debris was captured after rainfall of approximately 50 mm. (Image courtesy CQUniversity Gladstone Environmental Centre)

> litter is unsightly, unhealthy, damages the environment, contributes to pollution, and harms wildlife; it is also costly to clean up

Litter reduction techniques

There are a range of devices and methods to reduce litter. These range from legislation on industry, business, councils, and the like, to reduce litter at source through altering processes and installing mitigation devices, through to anti-littering campaigns aimed at the general public. A range of anti-litter devices are discussed here.

Biofiltration

Biofiltration refers to using plants to actively filter pollutants from a water body. Plants can be used to actively filter gross pollutants such as litter and rubbish from a system, to trap suspended sediments and also take up various chemicals such as heavy metals.

Process

1. Decide on the appropriate vegetation necessary to filter out the pollutant.
2. Remove gross pollutants with an appropriate screen.
    - » In an aquatic system, emergent reeds can be used as a gross pollutant trap.
3. Pass the water through a sediment trap or settling pond.
    - » This may help prevent smothering of fine aquatic plants with suspended sediments during flow events.
4. Use a mix of floating, anchored and emergent aquatic plants to absorb pollutants via their root systems.
    - » Native species should be sourced as many introduced aquatic plants have the capacity to become serious weeds.
5. Introduce oxygen to the water via riffle beds or a waterfall to help microbiological action on pollutants in the water.

Image of vegetation planted designed to help screen a coal terminal's impacts, by reducing dust, noise and light pollution as well as creating a more appealing view, RG Tanna Coal Facility, Clinton, Gladstone.

Tips

» Areas of standing stagnant water can provide breeding areas for mosquitoes and other insect pests. Maintaining flow or agitating water may help minimise this. Maintaining a natural biodiversity in the stream with fish, frogs and other aquatic life can help maintain a balance in pest species.

» Vegetation can also help screen out noise, dust, light pollution and unsightly infrastructure.

Images of biofiltration. Top left: Floating biofiltration beds; aquatic vegetation is planted to harvest pollutants from the water, Riverston Rise Estate, Boyne Island. Top right: A waterfall and fountain to add oxygen to the water body to assist microbial action, Kirkwood, Gladstone. Bottom left and bottom right: Emergent aquatic plants along the edges of ponds to help filter gross pollutants from entering the water. Note the warning sign to alert to the dangers of deep water, Riverston Rise Estate, Boyne Island.

Gross pollutant traps

In efforts to prevent large items of rubbish from entering stormwater drains, or exiting from them into rivers, creeks or the marine environment, some local government agencies have fitted gross pollutant traps to the entrances or outflows of major stormwater drainages. These cage-like structures trap larger items of rubbish and prevent it from entering the drains, or if fitted on the outflow, prevent large items from being washed from drains into the environment.

Process

1. Gross pollutant traps are generally constructed by experienced contractors and require approvals from local government, as a minimum.
2. Use urban debris surveys to determine the target drain inflow or outflow.
3. After consulting the relevant government agency, select design for an appropriate pollutant trap. Design considerations must include:
    - » public safety
    - » hydrological flow. It must not act as a barrier to flow and create possible flooding issues
    - » serviceability. It must be accessible for cleaning and designed so trapped wastes can be easily collected.

4. Ensure all legal requirements for installation are met, including regular planned trap servicing by waste contractors.
5. Contractors install trap.
6. Trap is monitored for efficiency and cleared of debris regularly.

Socks

Socks, stockings or bunds may be used to trap sediments in overland water flow by impeding the water flow, slowing its velocity and causing deposition of sediment load. Socks and stockings may also be used around pollution point sources to actively absorb pollutants such as oils and chemical spills or used at entrances to stormwater drains to minimise pollutants entering the drainage system. They work in a similar way to sediment control devices such as coir logs and silt fences.

Process

1. Identify the point source of pollutants or the area of dispersal into stormwater drainages.
2. Select a suitable product for the identified run-off.
    - » Certain geofabrics can be used to make absorbent bags and socks.
    - » Certain commercially available spill barriers and bunds may be useful for oil or petroleum products and various chemicals.
3. Install socks or bunds as required and anchor firmly in place.
4. Socks or bunds may need replacing or maintaining once saturated with chemicals or when sediments threaten to flow over the barrier.

Images of socks. Far left: Hay bales installed to minimise contaminants entering a wetland from an industrial site, Wapentake Wetlands, Gladstone (Image courtesy Conservation Volunteers Australia, Gladstone). Left and abovet: Geofabric sandbags and silt fence to minimise sediments in run-off into creek systems, Boyne Valley.

Drain stencils

Drain stencilling or fixing plaques to stormwater drains is designed to educate urban residents of the fate of water and other contaminants they may pour down local stormwater drains. The common message stencilled on drains is "this drain leads to the sea".

Process

1. Decide on area to be targeted for drain stencilling.
2. Obtain necessary approvals from local council or land owner.
3. Decide on appropriate message.
    - » Messages should be brief and to the point.
4. Arrange stencilling equipment or purchase drain plaques, if using.
5. Clean dirt, grass, etc. off the drain area and apply stencil.
6. Promote the drain stencilling activity in the local area.
7. Engage local assistance, if possible, for example, local school children or a community group.
    - » This can improve buy-in and awareness from local residents and spread the message about drains leading to the sea.
8. During stencilling activities, ensure safety of participants, especially if near busy roads and if using aerosol spray paints.

Tips

- » Use a weatherproof paint for stencilling.
- » If using plaques, affix them with stainless fixings drilled into the concrete of the drain.
- » Combine this technique with clean-up activities to further increase its impact.

Images of commercially available drain components and plaques labelled with messages to protect waterways, Gladstone.

Variations on technique

1. Commercially available drain pits that include pre-stencilled messages are available.

Cigarette butt bins

Cigarette butts are a major component of urban rubbish and vast quantities end up in the marine environment. They are resistant to degradation and laced with toxic chemicals. They are typically listed as a top 10 items found in litter and marine debris surveys.

Images of cigarette butts. Left: Count the butts! Cigarette butts lining a beach. Right: Cigarette butts collected from a single stormwater drain outflow after three separate rain events, Gladstone Central. (Source: CQUniversity, Gladstone)

Process

1. Identify 'hot spot' location where cigarette butts are likely to originate by completing litter surveys. Investigate current bin and cigarette bin services in the area. This is likely to be an appropriate site to install a cigarette butt bin, if facilities are not available.
2. Meet the legalities of bin installation.
    - » This may need approval from council or building owners.
    - » A planned method to service the bin needs to be agreed upon.
3. Bins should incorporate a place to stub out the butt end to prevent fire.
4. Install appropriate signs.
5. Monitor bin use and cigarette butts found in litter surveys to measure the butt bin's success.

Variations on technique

1. Personal butt bins can be made of 35 mm film canisters, breath-mint containers or similar small containers with a secure lid. Smokers can use these to dispose cigarette butts when away from a butt bin or general waste bin.

Images of a butt bin located in the centre of Gladstone. Right: Not everyone will use the butt bin!

Tangler bins

Discarded fishing line can be major hazard for marine life. Ingestion and entanglement are major causes of trauma and death to iconic marine megafauna. Tangler bins have been promoted by Local Marine Advisory Committees, Oceanwatch, CoastCare and other organisations as a simple way to discard unwanted fishing line, bait bags and other fishing debris safely and easily.

Process

1. Carry out litter surveys of popular fishing spots, boat ramps and so on, to identify sites for installing tangler bins.
2. Ensure all legalities are met with respect to local government, land owners etc.
3. Ensure a waste contractor is engaged to service the bins.
4. Affix tangler bins to appropriate post or structure at the designated location using corrosion-resistant fittings.
5. Ensure the endcap is fitted with a lock and make keys available to designated contractors.
6. Promote the use of tangler bins via fishing clubs, marine rescue, schools and other organisations.
7. Affix a sign to the post or the bin, advocating its use.

Images of Tangler bins installed at popular fishing and boating locations around Gladstone. (Image on right courtesy CQUniversity, Gladstone)

Resources

» Tangler bins are simple to make using poly pipe and a few plumbing fittings readily available at most hardware and plumbing supplies stores.

» Tangler bins can be built in various sizes. The most common size uses 90 mm diameter plastic downpipe, a 90 degree elbow and a push- or screw-on end cap.

Variations on technique

1. Length and diameter of the tangler bin can be varied using suitable poly pipe to build larger models for siting in popular fishing spots, or smaller models to fit unobtrusively in private boats or for shore-based recreational fishers to carry.

Quantification

As can be expected from previous examples, quantifying the project area for litter mitigation may cover an entire catchment, a whole city or suburb. The actual areas targeted for litter mitigation will generally be restricted in distribution. Some activities may occur project-wide, such as litter clean-up activities, but the majority of treatment activities may be highly targeted at litter point sources; perhaps a gross pollutant trap on an urban drain or sediment containment ponds and biofiltration measures on a new urban subdivision. Likewise, the benefit areas associated with different treatment methods will vary.

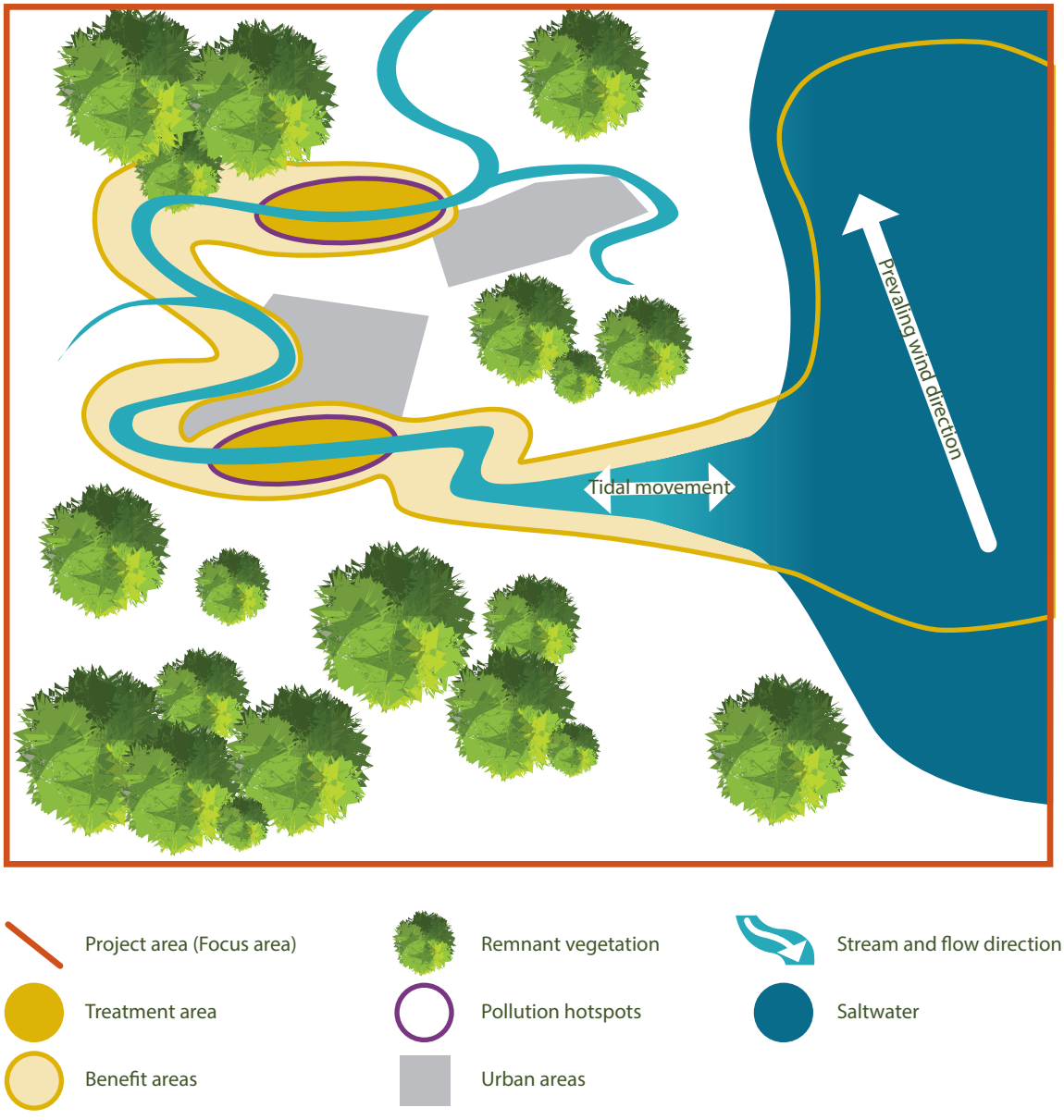


Diagram showing project area, treatment areas and benefit area associated with litter mitigation and showing seasonal variation.

In the above example, concern over development along an estuary leads to a local catchment care organisation seeking funds to target litter flowing to the sea. The group centres their project area on the estuary but previous studies show wind and currents deposit a large amount of marine debris on a beach to the town's north. Two main sources of litter in the town are identified: an open urban drain and a creek system that flows through an area of new developments. The developers design a system of sediment traps and biofiltration ponds on the creek and the group successfully lobbies for a gross

pollutant trap to be installed on the urban drain. To raise awareness, the group holds a major clean-up activity focussed on the main part of town, on the estuary itself and smaller scale debris clean-ups are held on the beach to the north.

The benefit areas associated with the gross pollutant trap and the sediment containment pond extend the full length of the estuary due to its tidal nature. It also extends out to sea where wind and currents further disperse pollutants. Prevailing strong winds and currents in the summer mean the benefit area in summer is greater than in winter. This is confirmed by studies of the drift of marked debris. The presence of the eddy currents also alters the predicted distribution of the pollutants, carrying them against the prevailing current at the estuary mouth. The localised clean-up of the main part of town engenders a community pride and the benefit area reflects this as throughout the community more care is taken to ensure rubbish is disposed appropriately and council reports that less litter is being dumped illegally adjacent to the town.

Further reading

Marine Debris Survey Form
http://www.tangaroablue.org/resources/data-sheet.html

Keep Australia Beautiful Urban Rubbish Survey Form
http://kab.org.au/wp-content/uploads/2012/05/Neighbourhood-litter-count.pdf

Allsopp, M, Walters, A, Santillo, D and Johnston, P. Plastic Debris in the World's Oceans, Greenpeace. Amsterdam
http://www.unep.org/regionalseas/marinelitter/publications/docs/plastic_ocean_report.pdf

Commonwealth Department of Environment and Energy Species Profile and Threats Database Listed Key Threatening Processes
http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl

Tangaroa Blue, Marine Debris Management Plan For Cape York Peninsula and the Torres -Strait Islands, Far North Queensland, Australian Marine Debris Initiative

> localised clean-up of the main part of towns engenders community pride

Pest Animals

Pest animals have significant impacts on Queensland's primary industries, natural ecosystems, and human and animal health. Pest animals are usually defined as non-native (feral) animals that have become a nuisance due to their negative impacts on the natural environment.

This chapter discusses common animal pests, impacts of pest animals, monitoring, control and management techniques.

At the end of this chapter there is guidance on quantifying pest animal management for evaluation and reporting; by identifying treatment area and measuring benefit area in an ecosystem.

What are pest animals?

Pest animals have significant impacts on Queensland's primary industries, natural ecosystems, and human and animal health. Pest animals are usually non-native (feral) animals that have become a nuisance due to their negative impacts on the natural environment. Generally, these animals having few natural predators, high birth rates and high adaptability to a wide range of ecosystem variables, which allows them to out-compete native animals. In certain situations, the natural balance between predator and prey or availability of food or water may also allow certain native species to attain pest proportions. This is the case with certain kangaroo species, which can breed whenever there is readily available water. Free-flowing bore drains can provide year-round water and allow kangaroo numbers to reach pest proportions. Common pest animals in Central Queensland include pigs, goats, horses, deer, cattle, foxes, wild dogs, cats, cane toads, carp, tilapia and live-bearing fish such as mosquito fish, guppies and swordtails.

Biosecurity Queensland has fact sheets that contain information on the biology, ecology, impacts from and various control options for common Queensland pest species.

Why manage pest animals?

Australia has unique ecosystems that have evolved in isolation from the rest of the world. Introduced animals may out-compete native species and reduce their numbers so much that unique Australia animals become endangered, or in severe cases, extinct. It is necessary to manage pest animals to minimise these negative impacts on native animal species. Pest animals may also degrade the natural environment, damage agricultural and forestry crops and impact infrastructure. They may also harbour further pests and diseases and contribute to weed dispersal. Pest animal impacts may have a serious economic cost. For example, rabbits are estimated to cost Australian agriculture some $200 million per year.

Left: Image of degraded habitat from feral pig activity in Kroombit National Park. (Source: Queensland Parks and Wildlife Service)

Pest animal impacts

Pest animals may have a range of impacts that require them to be managed. These impacts may include:

- predating on native species, their young or eggs
- competing for resources including food, shelter and breeding sites
- degrading the natural environment through over-grazing, browsing, excavating burrows and runs, damaging soil structure
- degrading wetlands and riverine habitats through burrowing, stirring up sediments and fouling water bodies
- degrading wetlands through nutrient enrichment (from dung and urine)
- acting as reservoirs of infectious diseases, which can impact native species populations
- transmitting wildlife diseases, stock diseases and aiding weed dispersal
- possessing toxins that may poison unwary predators.

Image captured of fox predation on turtle nest.

Declared pest animals

Biosecurity Queensland is responsible for coordinating the management of pest impacts from introduced mammals, reptiles, amphibians, locusts, ants and fish. Local governments are also required to have a pest management plan.

Pest animals are covered under the *Biosecurity Act 2014* and are listed as prohibited and restricted matter, similar to weeds. Prohibited species are generally not found in Queensland or, if present, they are isolated outbreaks and require prompt action to eradicate them. Restricted matter are species that may already be found in the state and require actions to manage, reduce or contain their spread. As outlined in the invasive weeds chapter, seven categories are recognised under restricted matter in the Act.

Category 1 and 2 refer to notifying relevant authorities should a pest species be found. Category 3 restricted matter must not be sold, traded or otherwise distributed or dumped into the environment; and Category 4 material must not be moved. Category 5 regulates possession or control of restricted matter. Category 6 refers to not feeding restricted animals and Category 7 requires the destruction of restricted species should they be caught. Species may fall into several categories of restricted matter.

For example, rabbits are listed as Categories 3, 4, 5 and 6 restricted matter. This means rabbits must not be:

- given away, distributed sold or traded
- moved within Queensland
- kept by a person or in their control
- fed (except during baiting programs)
- released into the environment or disposed of other than in the way prescribed under a regulation.

Table 5

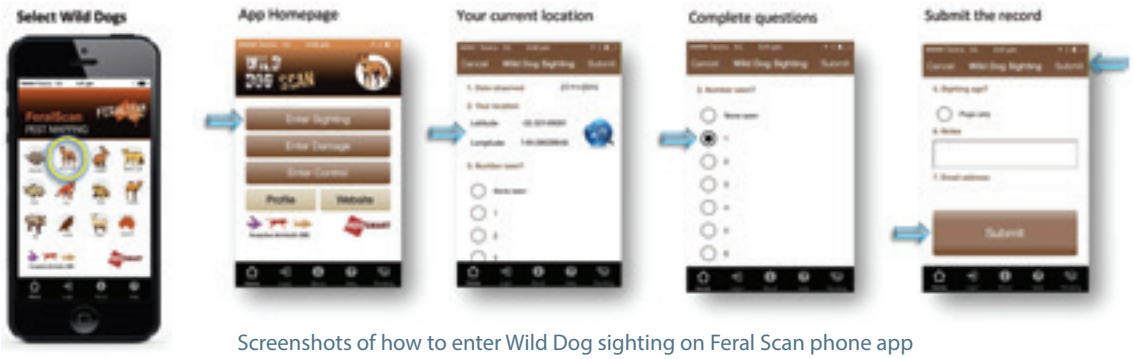
Common pest animals found in Central Queensland, including those listed and categorised under the Biosecurity Act 2014.

Common name	Scientific name	Biosecurity category	Range of impacts
Wild pig	*Sus scrofa*	Categories 3, 4 and 6	Harbours disease, predation, environment damage, wetland degradation
European red fox	*Vulpes vulpes*	Categories 3, 4, 5 and 6	Predation, competition with native predators, harbours disease
Cat	*Felis catus*	Categories 3, 4 and 6	Harbours disease, predation
Wild dog	*Canis familiaris, Canis familiaris dingo, Canis lupus dingo, Canis lupus familiaris*	Categories 3, 4 and 6 for wild dogs Categories 3, 4, 5 and 6 for dingos	Predation, harbours diseases, economic impacts
Deer (rusa deer in CQ)	*Cervas timorensis*	Categories 3, 4 and 6	Grazing and browsing impacts
Horses	*Equus caballus*	Undeclared	Grazing impacts, spreads disease, trampling, competition, fouling water sources
Goats	*Capra hircus*	Categories 3, 4 and 6	Browsing impacts, spreads disease, erosion impacts
Non-native birds	*Indian Myna, European Sparrow*	Undeclared	Competition, disease reservoirs and vectors
European rabbit	*Oryctolagus cuniculis*	Categories 3, 4, 5 and 6	Grazing and browsing impacts, competition, erosion impacts, disease vectors and disease reservoirs
Cane toad	*Rhinella marina*	Undeclared	Toxic, predation, competition
Tilapia and other introduced fish species such as mosquito fish and carp	*Oreochromis mossambicus, Tilapia mariae, Gambusia, Cyprinus carpus*	Categories 3, 5, 6 and 7	Predation, competition, degrading aquatic habitat

Further information including species descriptions, adverse impacts and control methods may be found on PestSmart, Department of Environment Heritage and Protection's Wildlife and Ecosystems, Business Queensland's Restricted invasive animals, Department of Agriculture and Fisheries Pest Animals, and local governments pest animals information.

Mapping sightings and den locations

Knowing the location of pest animals is one of the first steps in developing a management strategy for the species in question. Without accurate data concerning range and abundance, the location of breeding populations, home range, dens and refuges, it is extremely difficult to ascertain the scale of the problem and plan a management strategy. The Queensland Government maps the distribution of many declared pest animals on a regular basis. This information can show how infestations are spreading, the efficiency of eradication or containment of species, and identify possible areas at risk. Public input is often crucial to help monitor the spread of pest animals and identifying dens and lairs through FeralScan and the Department of Agriculture and Fisheries' pest distribution maps.



Screenshots of how to enter Wild Dog sighting on Feral Scan phone app

Photographic monitoring

Typically, wildlife is shy of humans. Except for birds, some lizards and a few kangaroo species, many people do not notice much of Australia's wildlife or indeed many pest animals. Often pest animals are secretive, shy and only active in the cool of the evening, early morning or are nocturnal, actively hunting and foraging overnight. As such, it can be difficult to observe them, make positive identification or their habits. Increasingly, technology is being used to study animal behaviour. This includes mark and recapture programs that use radio collars or satellite tagging systems and the opportune use of concealed cameras with remote shutters, listening devices and data loggers.

Wildlife infra-red motion-sensor cameras

A motion-sensor infra-red camera is a useful method of observing wildlife. This allows the camera to be concealed near a known wildlife haunt; the camera records an image when the infra-red sensor is triggered by movement across the beam. This method can be coupled with baits or attractants to entice animals into range and the infra-red beam is not visible. Cameras can be camouflaged and secured in place so they are not easily visible, making them less likely to be stolen or vandalised. It may be necessary to establish the camera for an extended period as animals may be shy of human traces, especially odour after the camera is installed. It is important to ensure no branches or grasses obstruct the beam or they may trigger the camera when moved by the wind. Depending on the land tenure and landowner requirements, it may be necessary to install signs advising of the camera's use, especially in public places.

Images of motion-sensor camera capturing pig activity at Kroombit Tops National Park. Left: Infra-red for night vision. Right: Image captured during the day. (Source: Queensland Parks and Wildlife Service)

Pest animal control techniques

Pest animal control, in much the same way as weed control, requires a sound knowledge of the pest species, its behaviour, habits and range. To be effective, control methods will generally need to be carried out cooperatively among neighbouring landholders, and in an integrated manner. Some pest management techniques use chemicals that may be highly toxic to humans, native wildlife, and domestic animals or stock. Other control methods such as shooting, electrofishing and trapping may also pose significant risk to the general public.

Before attempting any form of pest animal control it will be necessary to check for user guidelines and the requirements for licences and permits with State and local government authorities. Pesticides must be used in accordance with guidelines issued by the AVPMA. Biosecurity Queensland is the government department to contact for advice on pest management in Queensland.

The welfare of the pest animal must also be considered in any control program. It is not acceptable to treat pest species inhumanely and the Government has developed codes of practice for control options and standard operating procedures for particular control options. PestSmart has codes of practice and standard operating procedures for humanely controlling key pest animal species.

Protecting turtle nests from predation

Three species of marine turtles and six species of freshwater turtles are known to nest in the Fitzroy Basin. Of these, all three marine turtle species, and three of the freshwater turtle species, are listed as threatened under the EPBC Act. Threats common to both marine and freshwater species are nesting habitat loss or degradation and impacts from predation on eggs and hatchlings, especially by introduced predators such as pigs, foxes and wild dogs. Native goannas also prey heavily on nests. To minimise nest predation, a combination of exclusion fencing, shooting and baiting is used to minimise predator impact on turtle nests. Further nest protection measures, such as predator exclusion devices, are also regularly employed. A qualified contractor will need to be used when working with turtles.

Process

1. Obtain required permits and approvals to interfere with listed endangered species prior to nesting season.
2. Research species involved and their nesting behaviour.
    - » This determines timing of nest protection activities, and the size of mesh used for nest protection.
3. Identify pest species.
    - » This will determine what pest exclusion material will be required.
4. Assemble required nest protection materials – wooden stakes, plastic sand pegs or steel pegs, plastic garden mesh or thin wire mesh (50 mm square) for foxes, single dogs or goannas.
5. Identify nest site and where the eggs are buried.
    - » Mesh needs to be centred over the actual egg chamber.
6. Clear debris from soil surface and level the ground around the nest site to the dimensions of the mesh piece.
    - » Mesh must be laid flush with, or buried beneath, the soil surface to prevent predators burrowing under it.
7. Centre 1 m x 0.9 m or 1 x 1.2 m mesh square over nest site. Mark the centre of the nest with a piece of flagging tape tied to the mesh over the nesting chamber.
8. Peg mesh down securely over the nest site.
    - » In sand, use hardwood stakes angled to pull the mesh taut.
    - » In loam soils, use steel pegs or pins to secure mesh.

9. Ensure edges of the mesh are buried in the substrate to prevent predators burrowing under the mesh.
10. Check the nest protection measures regularly as packs of dogs, or repeated attempts may damage the exclusion mesh.
11. Remove all nest protection materials after the nest has emerged.

Tips

» Plastic garden mesh will be unsuitable for protecting against pigs. An aluminium mesh security screen secured over the nest may be necessary to protect against pig predation.

» With marine turtle nests it is necessary to cut out every second strand of mesh leaving 50 mm x100 mm gaps in the centre over the egg chamber. This allows the hatchlings to emerge through the mesh.

» If large numbers of nests need protection, alternatives such as preventing pest species accessing the nesting area may be more effective.

Images of nest protection. Left: Installing a fox exclusion device over a flatback turtle nest. Note the centre mesh is clipped to allow the larger flatback hatchlings to escape the nest. Right: Recovering the nest back to original depth, Facing Island.

Variations on technique

1. Using wire mesh or security screen cages that are well-anchored over nests may give protection from feral pigs.
2. Permanent hatcheries can be constructed in centralised locations and eggs relocated to these safe havens. Egg relocation requires specialised training, but is an accepted method for preventing egg mortality through predation and erosion.

Traps

Trapping can be a useful means of controlling pest animals in areas where pest numbers are low or bait-shy. They may be useful for mopping up pest animals that have escaped shooting or baiting programs or in urban areas where these methods may not be suitable. Trapping is labour-intensive and may be negatively perceived by members of the public. Trapping programs must be carried out ethically and traps checked regularly to prevent trauma to captured species. A number of trapping devices are available, including tunnel traps, cage traps, leg-hold and collar traps. Cage traps are often available from local government for trapping feral cats, and this is the method considered here. Other forms of trapping are usually best left to licensed pest management contractors.

Process

1. Identify pest species.
    - » This determines timing of activities, size of trap and bait type.
2. Become familiar with trap setting and operation.
3. Prepare bait or attractant.
4. Place trap in area of known pest species habitat.
    - » Traps may be left closed and unbaited so pest species become accustomed to them.
    - » Traps may need to be secured to prevent them being stolen or dislodged.
    - » Traps should be in the shade, sheltered and concealed.
5. Bait and set trap (usually in the afternoon or evening).
    - » Usually traps possess a mesh enclosure or hook to place bait on so it is harder to remove.
    - » Set trap mechanism — this will vary according to trap design.
6. Check traps as early as practical in the morning.
    - » Trapped animals can overheat or dehydrate quickly, especially when stressed and confined.
    - » Stressed animals may injure themselves trying to escape from the trap.
7. Destroy captured pest animals humanely.
8. Lodge records of species trapped with a responsible pest management officer.

Tips

- » Do not smoke, wear strong deodorants or insect repellents when baiting and setting traps.
- » Leave traps unset and closed for a few days so target animals become accustomed to their presence.
- » Check traps daily.
- » Ideal baits are generally oily and strongly smelling.
- » Free feeding may help lure pest species into an area prior to trapping.
- » Occasionally a "Judas" animal may be trained to enter a trap and draw other animals to the trap.
- » Establishing pig traps near a water source can be effective in dry periods as they will not wander far from a reliable water source.
- » Sump oil has been reported as highly attractive to feral pigs.

Image of a cat trap at Wapentake Wetlands, Gladstone. (Image courtesy Conservation Volunteers Australia)

Variations on technique

1. For larger species such as feral pigs, cattle and horses, more permanent structures may be built using drift fences to guide animals into a trap via a one-way gate or race. This style of trap may be used to capture more than one animal at a time.

Baiting

Using poison baits is often a cost-effective control measure for pest animals. Baiting can be highly effective, providing suitable baits are used, but is non-selective and other non- target species may also be poisoned. Non-target species may suffer primary poisoning from taking poison baits, or secondary poisoning from eating the carcasses of poisoned animals. Baiting may be used for controlling pigs, dogs, foxes and cats as well as rats and mice. Poison baiting for pigs, dogs, foxes and cats usually involves 1080, and has specific requirements for use by qualified contractors.

Process

1. Identify the pest species' range and habits.
2. Select appropriate bait for controlling the desired species.
    - » Certain baits may not be suitable for certain species.
    - » Certain chemical baits are not recommended for use due to animal welfare issues.
    - » Certain baits may not be used in areas where off-target poisoning of domestic or stock animals may occur.
3. Lay baits within the designated baiting area. Baits should not be used within 5 km of an urban area or within 1 km of any building.
4. Install appropriate signs to warning public that baiting is in progress.
5. Monitor bait stations and restock if necessary.
6. Dispose of any carcasses discovered by burning or burying them to minimise the possibility of secondary poisoning.

Tips

- » Non-target animal mortality can be reduced by selecting an appropriate type of bait. For example, using rabbit carcasses as bait is likely to poison wedge-tailed eagles as they regularly scavenge dead rabbits. Likewise, leaving poisoned carcasses in the open may lead to secondary poisoning. Where possible, carcasses should be buried or burnt.
- » Conducting a round of camera-monitored non-toxic baiting prior to introducing toxic baits is an effective way to determine what non-target species may be in the area. It gives the ability to adapt the baiting program, if necessary. Most pre-made baits such as PigOut are available in both non-toxic and toxic forms to allow for pre-bait monitoring and use the same general ingredients.

Images of poison bait signs, Kroombit Tops National Park.

Fumigation

Due to the toxic nature of many fumigants, this is a method usually employed by suitably trained and licenced pest management contractors. Using car exhaust fumes is no longer deemed humane and is actively discouraged. Gas is often used on rabbit warrens and fox dens. Using aluminium phosphate tablets is discussed in detail here, as these are generally the safest method of fumigation available. Qualified contractor will need to undertake works.

Process

1. Identify the location of the den or warren.
2. Identify if burrows are active and occupied by pest species.
3. Search out all burrows, both active and inactive.
4. If using aluminium phosphate tablets for rabbit control, wrap tablets in moistened paper and push into the burrows as far as possible.
    - » The tablet reacts with water, releasing phosphine gas, which permeates the burrow and killing its occupants.
5. Stop all entrances to the burrows using scrunched-up paper and then backfill with soil.
6. Check for gas leaks. An ammonia smell indicates a leak. Re-seal burrow as necessary.
7. Check and re-fumigate after one week if there is still evidence of activity in the den or warren.

Electrofishing

Electrofishing is a method of capturing fish by using an electrical field that disrupts the fish's electrical system, affecting its nervous and muscular systems. Creating an electrical field in the water body can force fish to swim involuntarily toward the electrode, and also induce narcosis and taxis where the fish becomes immobilised by the electrical current and allowing it to be netted. Obviously, mixing electricity and water has associated risks and all operators must be fully trained. Equipment must also be certified and regularly safety-tested. All electrofishing personnel require heart and respiratory medical clearance prior to being involved in any electrofishing activity. Electrofishing is regulated by a code of practice in Australia and operators must be licenced.

Process

1. Select and check equipment for serviceability and safety, especially safety equipment.
    - » Electrofishing equipment must be checked by a licenced electrician every 12 months.
    - » Waders and waterproof gloves must be checked for tears or damage each time they are used.
2. Ensure all personnel undergo medical screening prior to participation.
3. Research target species.
    - » Tilapia are less susceptible to electrofishing than many native species and rapidly recover.
4. Select appropriate site. Electrofishing is only suitable in waters with a low conductivity of less than 700 mSiemens, and will not work in saline water.
5. Operators must wear full waders and insulated linesman's gloves.
6. The electrofisher operator acts as supervisor and safety coordinator of all fishing operations.
7. Place both cathode and anode probes into water and adjust to operational voltage.
8. Using an insulated net, an assistant scoops immobilised fish from water.
9. Sort and catalogue fish, and return them to the water as soon as possible.

Tips

» A smooth current DC voltage should be used, and current should not be pulsed or spiked as it can injure fish.

» Certain fish species can be injured at quite low voltages, so it is best to start low and build voltage until it is effective.

» Multiple conductivity readings should be taken at each site and voltage adjusted accordingly.

Image of CQUniversity staff member operating a backpack electrofisher to survey for freshwater fish. (Image courtesy CQU, Gladstone)

Variations on technique

1. Electrofishing can be used to guide and drive fish toward set nets.
2. Electrofishing has also been used to prevent fish entering intakes and in water structures.
3. There are three main styles of electrofishing unit: a bank-side unit, a portable backpack unit and a boat-mounted unit.
4. eDNA sampling of water bodies is an emerging technique being used to identify whether tilapia are present in a water body. (Refer to PestSmart's 'The utility of eDNA as a tilapia surveillance tool').

Quantification

Managing and controlling pest animals can have a far greater impact than within the immediate project area and depends on the home range of the species being targeted. For example, carrying out a pig control program adjacent to a turtle nesting beach may have a beneficial impact on the environment throughout the entire pig population's range. It must be noted though, once a wide-ranging pest animal population is removed from an area, that area may quickly be recolonised by animals ranging from adjacent habitats. This is one of the reasons that a coordinated and neighbourhood-wide approach is often necessary with pest animal management. It also highlights the need for continued vigilance and regular monitoring as some pest species are secretive, shy and may roam large distances in a short time, quickly reinfesting areas vacated after control treatments have been employed.

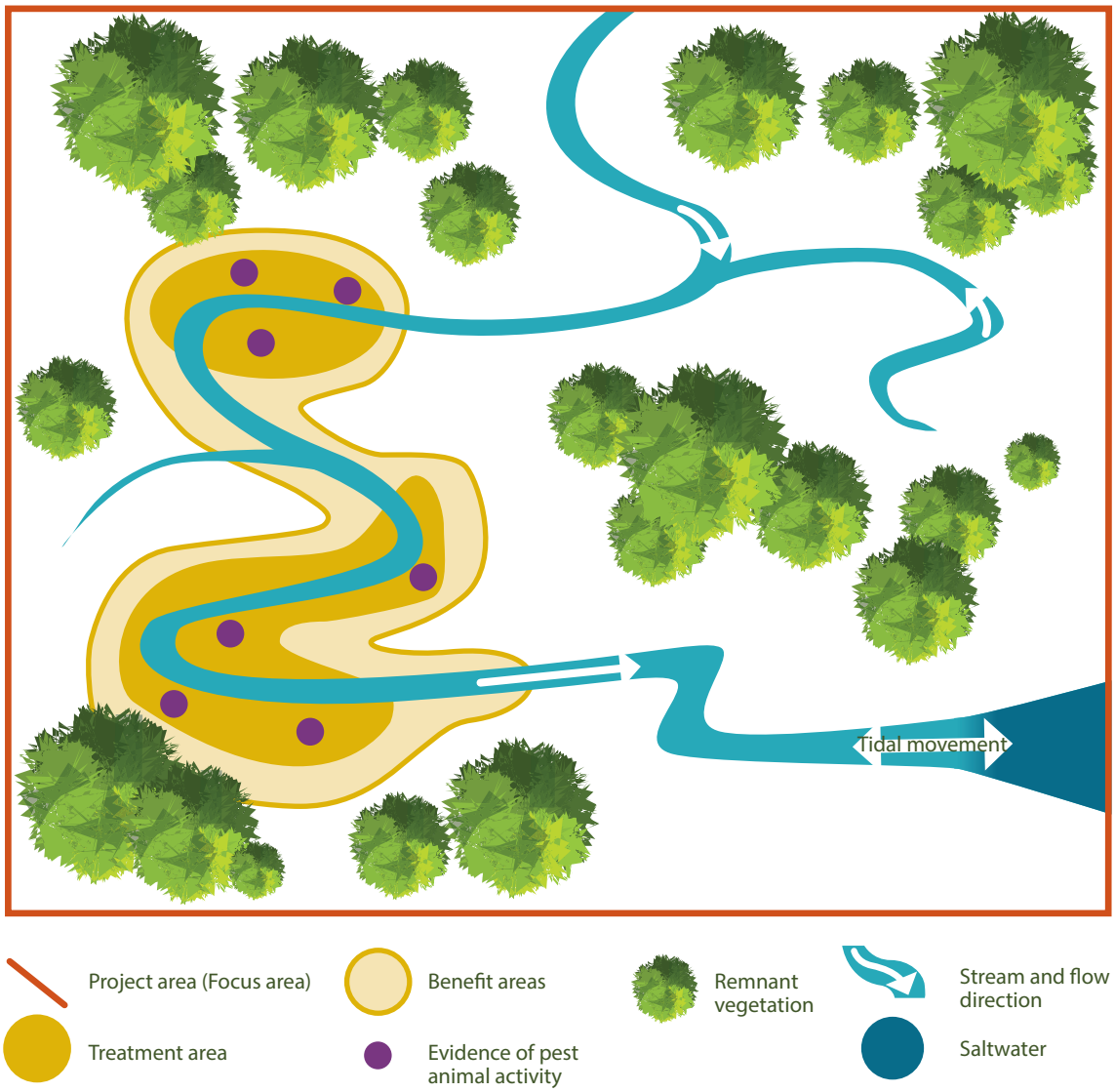


Diagram showing the importance of vigilance and monitoring pest animals in respect of project outcomes.

As shown in the diagram above, evidence of pest animal activity (purple areas) which could include pest animal sightings, den locations, tracks, signs of predations, can often be found in multiple locations. Implementing pest animal control (organge treatment area) around known and active evidence locations aims to increase effectiveness and maximise the benefit area. If successful, the benefit area of pest control will encompass the home range of the target pest species.

Table 6

General home ranges for various pest species in Queensland, taken from species information fact sheets produced by Biosecurity Queensland. Note the home ranges specified are highly variable and are dependent on sex, age class, breeding status, season, availability of resources such as food, shelter and water, habitat and prevailing weather.

Pest animal species	Home range
Pig	Female and juvenile pigs usually live in small family groups with a home range of 2–20 km^2. Adult males are typically solitary, with a home range of 8–50 km2.
Goat	Goats occupy a home range usually centred around a water supply. In arid areas, this range can be up to 379 km^2. In drier periods, when water is scarce, home ranges become small as animals remain close to permanent water.
Cat	Dominant male cats may have territories up to 8 km^2, while the territories of females are smaller and may even be halved while rearing kittens.
Wild dog	The home range can vary in size according to the productivity of the country: from 9 km^2 in fertile areas, to 300 km^2 on the plainlands.
Horse	70 km^2 range and may move 50 km per day within their range.
European red fox	Rural home ranges in Australia are about 500 ha; however, this can vary widely and depends on resource availability. Dispersal behaviour varies between males and females and between individuals of the same litter. Males typically disperse further than females and distances of 300 km have been recorded.
Deer	Observed to occupy a defined home range (size unavailable)
European rabbit	0.2 ha to 2 ha (0.002 km^2-0.02 km^2) Young may disperse up to 20 km from the home warren.
Cane toad	Nomadic and move 200 m per night
Fire ant	No available data
Non-native birds	No available data
Noxious fish	No available data

Further reading

Elsworth P, 2016. Pest Animal Research, Impacts of Rabbits on Horticulture
https://www.daf.qld.gov.au/plants/weeds-pest-animals-ants/invasive-plant-and-animal-science/research-programs/pest-animal-management

Queensland's declared pest animals (including insects)
https://www.business.qld.gov.au/industry/agriculture/species/declared-pests/animals

Pest fish identification
https://www.daf.qld.gov.au/fisheries/pest-fish/noxious-fish

FeralScan and PestSmart
http://www.feralscan.org.au/

Queensland Department of Agriculture and Fisheries Pest Mapping
https://www.daf.qld.gov.au/plants/weeds-pest-animals-ants/pest-mapping

Queensland Department of Agriculture and Fisheries, Biosecurity
https://www.daf.qld.gov.au/biosecurity

Commonwealth Government Invasive Animal CRC, 2015. Pest Smart Connect Humane Codes
http://www.pestsmart.org.au/animal-welfare/humane-codes/

Noble, TH, Robson, HLA, Saunders, RJ and Jerry, DR, 2015. The utility of eDNA as a tilapia surveillance tool. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia.
http://www.pestsmart.org.au/wp-content/uploads/2015/11/eDNA_tilapia_surveillanceFINAL.pdf

> managing and controlling pest animals can have a far greater impact than within the immediate project area

Homes for native wildlife

Australia has highly diverse wildlife; it is, in many respects, highly unique. In a fragmented environment, native animals are continually exposed to pressures from increased disturbance, predation and access to limited resources. Installing artificial homes for native wildlife may help complete ecosystem rehabilitation; species taking up residence may perform functions that help or improve natural regeneration.

This chapter discusses the importance of native wildlife and various types of artificial homes for native wildlife.

At the end of this chapter there is guidance on quantifying the installation of homes for native wildlife for evaluation and reporting by identifying treatment area and measuring benefit area in an ecosystem.

What is native wildlife?

Australian native wildlife are species that can be endemic (only found in Australia) or indigenous (found both within Australian and naturally elsewhere). That is, the species is generally restricted to Australia, adapted and evolved to fill specific niches and habitats within the Australian context and is present here as a result of only natural processes, with no human intervention.

Images of native wildlife Left: fitzroy river turtle (Rheodytes leukops). Middle: echidna (Tachyglossidae sp.). Right: flatback turtle (Natator depressus).

Why protect native wildlife?

Australia has highly diverse wildlife; it is in many respects highly unique to Australia and with minimal representation outside of the Australian continent. Australia was part of the ancient southern landmass Gondwana. Due to its long isolation and geological stability, Australia has retained plant and animal communities that have been lost elsewhere in the world.

The key to ensuring the survival of many native animals is protecting their habitat. They need food, water and nutrients, and places to breed and shelter from weather and from predators: keep the habitat, keep the animal. Wild animals often need adequate areas of bushland or wetland to survive and thrive. Where an animal's natural habitat has been cleared or reduced to small isolated patches, the local population is unlikely to survive. Therefore, national parks, other protected areas, and habitat that is retained on private land are critical for wildlife conservation (Department of the Environment and Heritage Protection, 2016).

Image of a sign notifying beach users that the beach is important turtle nesting habitat and advice on how the community can increase turtle hatchling survival.

Why encourage native wildlife by installing artificial homes?

In a fragmented environment, wildlife are continually exposed to pressures from increased disturbance. They often face introduced predators and compete for limited resources in habitats that are often of a minimum size and of limited carrying capacity. They may be exposed to disease and impacted by living in close proximity to humans.

The role many native fauna species play in the environment is often poorly understood and as such, the loss of species may have unforeseen outcomes for the health and proper functioning of an ecosystem. Native species may spread the seeds and spores of native plants. Many native plant species require the action of digestive enzymes to condition their seeds for germination. Native species may control pest species, or maintain a balance over species that would eat or damage native plant species. Others graze or browse plant species and prevent them becoming overly dominant. Some wildlife is crucial to plant pollination. Wildlife may also pay a pivotal role in conditioning the soil for germinating of new plant species.

Image of wildlife box at Rockhampton Botanic Gardens.

Australian wildlife is unique and is a major drawcard for international visitors, as such, it plays a large role in the economy through the tourism sector. Similarly, its uniqueness and its antiquity mean it is important to the history of life on Earth and is important for research and scientific studies.

Encouraging wildlife by installing artificial homes may help complete rehabilitation of a site as the species taking up residence may perform functions that help or improve the site's natural regeneration. For example, birds taking up residence in a hollow log may import seeds to the site that require passage through a bird's digestive tract for successful germination. This may help new plant species that would be unable germinate to become established. Installing artificial homes may provide native species with a place to shelter and avoid predation by introduced species. Homes may provide them with more opportunity to breed successfully, and ultimately perhaps out-compete exotic species.

> the role many native fauna species play in the environment is often poorly understood

Techniques for including homes for native wildlife

Hollow logs

One of the BioCondition monitoring criteria is the presence of large pieces of wood on the ground; this is taken as a measure of available habitats. Larger timber is also more likely to be decayed or termite eaten and hence have hollows that provide homes for a wide variety of animals. Smaller woody debris can also serve as habitat for smaller species.

Process

1. Retain all naturally occurring large diameter logs (>100 mm) on project sites.
2. If logs are moved into a site, ensure they are free from weed seeds, pests or disease.
3. Logs can be stacked in piles to create crevices and cavities.
4. Logs in creek systems cannot only provide wildlife habitat but also be effective for slowing water flow, altering stream dynamics and creating scours, which will lead to naturally excavated pools.
5. Logs can be wedged into trees to provide homes for tree-dwelling wildlife, birds and bats.

Tips

» When handling hollow logs, ensure that gloves are worn as centipedes, scorpions and spiders may already be living there.

» If burning an area as part of fire management, avoid burning log piles as these may be refuges for native wildlife.

» If collecting logs that are not being sourced from naturally found fallen debris in a project site, ensure they are ethically and responsible sourced.

Variations on technique

1. Piles of stones may provide habitat in areas where trees are lacking.
2. Smaller stacks of sticks and woody debris can provide habitat from smaller species.

Above top: Image of woody debris creating homes for native wildlife. Above: Flood debris provides a mass of structure to afford protection for a diverse range of native wildlife. Right: large broken branches placed among mulch create native wildlife refuges, Double Creek Calliope.

Image of hollow branches have broken from this large old blue gum (Eucalyptus tereticornis) leaving tree hollows for wildlife homes. The fallen logs also provide homes for terrestrial species.

Wildlife boxes

Old growth trees are a vital component of many Australian ecosystems. As trees age and limbs die and decay, tree hollows may form. These hollows provide homes for a wide range of animals. In the absence of old growth trees it may be necessary to replace these hollows with purpose-built wildlife boxes. Designs vary and the size and shape can be adapted to suit certain types of animal species.

Process

1. Determine what species you wish to accommodate.
2. Purchase or build your own wildlife boxes. Plans for a variety of species are available on the internet — see link below under resources.
3. Position wildlife boxes at respective height above ground.
4. Secure wildlife boxes to tree trunk or branches. Ensure fastenings are secure, weatherproof and capable of withstanding strong winds and storms.
5. Monitor boxes for unwelcome guest such as swarms of European bees, or ants.

Tips

» Do not paint inside of boxes. Wildlife may chew or gnaw the paint, which may be toxic to them.

» Ensure the outside is sealed to maintain a dry, cosy interior.

» Certain designs will require some mesh or perches to allow animals to climb the box's smooth walls.

» Ensure entrances and the dimensions of the box are of a suitable size for the intended species.

» Installing wildlife boxes in various sizes can provide for a greater diversity of wildlife.

Wildlife box at Tondoon Botanic Gardens, Gladstone.

Fish passages

All fish need to move along streams over scales of metres or hundreds of kilometres to:

» feed;

» spawn;

» seek shelter and refuge;

» enhance dispersal of young fish;

» counter downstream displacement following high flows;

» recolonise after droughts.

Image of the installation of fish passage at Moores Creek, Rockhampton

Alterations to waterways such as construction of road crossings, weirs and dams can form a barrier to fish migration. Many Australian species require slow moving water with small increments of height between each section of waterways in order to migrate successfully, especially juvenile recruits. Installing fishways aims to address the issues created by the barrier, which generally includes controlling the flow of water through a site specific designed structure that has a series of gentle flowing outlets connecting stepped pools from downstream to upstream of the barrier.

Images of various fish passages. Left: Fish passage at Amity Creek. Right: Fish passage at Lake Callemondah in Gladstone.

Fish hotels

Many urban waterways are regularly de-snagged, scraped and shaped to allow storm water to escape rapidly. In this modified habitat refuges for fish and other aquatic organisms are lost. Most coastal streams in Queensland are, in fact, far from ideal fish habitat areas as culverts, weirs, dams and pipes act as barriers to fish migration. Fish hotels provide artificial habitat in a similar manner to the artificial habitat for terrestrial and tree-dwelling wildlife. Fish hotels introduce structure into the water body to provide cover from above, to break the current and to provide havens within which fish can shelter. Typical fish hotels include structures constructed from logs bolted or chained together but they may be as simple as anchoring the stump of a large tree into a waterhole.

Process

1. Ensure water body has no human-made or natural barriers to fish migration.
2. Select a site that has a lack of fallen woody debris or physical habitat structures as well as considering permanency of water depth to keep artificial habitat submerged.
3. Select a suitable fish habitat design.
    - » This may need to be designed around stream maintenance criteria.
    - » May need to consider how the structure will be anchored to withstand peak flows.
4. Construct or place structure within aquatic habitat.
5. Monitor to ensure structure is performing as expected.

Image of a number of fish hotels prior to installation at Yeppen Lagoon in Rockhampton with staff from Rockhampton Regional Council, Australasian Fish Passage Services and Fitzroy Basin Association.

Quantification

Quantifying the impact of installing homes for native animals will show a beneficial area that is equal to the home range of the species that takes up residence in the provided refuges. This may be far larger than the actual treatment area and may extend beyond the boundaries of the project itself.

Treatment areas are small and restricted to areas of carefully identified suitable habitat in the overall project area. The benefits provided by the installed homes once they become occupied by the various target species is dependent on the species behaviour, its home range and its migratory habits, if any.

Further reading

Build your own Wildlife Nest Box: A guide for Western Sydney, Greater Sydney Local Land Services http://www.wires.org.au/Default.aspx?PageID=16515813&A=SearchResult&SearchID=2216910&ObjectID=16515813&ObjectType=1

> old growth trees are a vital component of many Australian ecosystems

Part ③
Ecosystems

Ecosystems are vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil (Sattler and Williams 1999, Vegetation Management Act 1999). Each ecosystem outlined in the following pages is commonly found in the region and aligns with the Queensland Government's Regional Ecosystems.

Each chapter provides a description of the typical habitat characteristics, vegetation, threats and pressures of each ecosystem as well as a guide to appropriate restoration techniques and plant species.

Part 3: Ecosystems

Coastal foredunes and beach

This chapter describes common coastal foredunes and beach ecosystem features, and typical threats and pressures. It provides guidance on recommended restoration activities suited to coastal foredunes and beach ecosystems.

Ecosystem description

A habitat type at the interface of the terrestrial and marine environments, coastal foredunes and beaches are characterised by a highly mobile substrate, exposure to salt-laden winds, occasional wave action, harsh sun exposure and high evaporation. Salinity is generally high, humus levels are low, nutrients deficient and fresh water is limited. Plant communities tend to be relatively simple.

Plants here are usually efficient colonisers. Tough groundcover species such as creeping grasses and low growing vines, beach spinifex (*Spinifex sericeus*) and goat's foot convolvulus (*Ipomea pes-caprae*) are prominent species. These pioneering species stabilise the dunes. As substrates stabilise, open woodland of coastal she-oak (*Casuarina equisetifolia*) often develops, with occasional stands of screw pine (*Pandanus tectorius*). A defined shrub layer is generally absent from coastal foredunes.

In the more protected dune swales — the depression between individual dunes —where moisture and nutrients may accumulate, a more diverse flora may develop, especially in the secondary dunes. In the more exposed swales, a shrub layer with scattered, often stunted, wind sheared and salt-scalded trees may develop. Scrambling vines may also be relatively common. In more sheltered swales, vegetation may include a rainforest element, and in wetter swales with seasonal water bodies, melaleuca species and cabbage palms (*Livistona decora*) may dominate.

Images of coastal foredunes at Lillies Beach showing coastal she-oaks on foredune and beach scrub elements in the dune swales.

> plants in these areas are usually efficient colonisers

Recommended plant species

Table 7

Recommended plant species for coastal foredune ecosystems

Common name	Botanical name	Mature height	Strata
Beach spinifex	*Spinifex sericeus*	0.4 m	Groundcover – grass
Dune love grass	*Eragrostis interrupta*	0.5 m	Groundcover – grass
Beach bean	*Vigna marina*	0.4 m	Groundcover – vine
Goat's foot Convovulus	*Ipomea pes-caprae*	0.4 m	Groundcover – vine
Coastal jack bean	*Canavalia rosea*	0.4 m	Groundcover – vine
Pigface daisy	*Carprobrotus glaucescens*	0.2 m	Groundcover - vine
Coastal she-oak	*Casuarina equisetifolia*	12 m	Tree
Screw pine	*Pandanus tectorius*	12 m	Tree
Necklace bean	*Sophora tomentosa*	5–8 m	Shrub or tree
Hickory Wattle	*Acacia disparrima subsp. disparrima*	8–10 m	Tree

Threats and pressures

The greatest threat to coastal foredune and beach ecosystems possibly arises from human actions. Much of this ecosystem is subject to the pressures of coastal development. Increased urbanisation, industrialisation and tourism development has reduced this ecosystem's natural values. Many dune systems have been subjected to hard landscaping, erection of coastal defences or modified with introduced plant species.

In other areas, uncontrolled access from both pedestrians and vehicles has exposed the dunes to the effects from wind, often creating serious erosion problems. When coupled with uncontrolled camping, lighting of fires and clearing of coastal vegetation, the foredunes may collapse. Under a climate change scenario, there is also the risk of elevated sea levels, and more frequent storm surges eroding the frontal dunes and allowing saltwater incursion into the water table. Storm surge action on the foredunes and beaches in Central Queensland has been quite marked in the past decade with many beaches losing dune structure and important buffer vegetation. Using mechanical means to clear storm debris from the beach and pushing it into the foredunes may also bury the seed bank at a depth beyond which it can re-establish.

Beach vegetation does not tolerate fire. Fires on the foredunes result in changes to the substrate and a loss of native vegetation. Coastal she- oaks in particular will be adversely affected by fire, often allowing the understory to be invaded by introduced grasses, vines and other weed species. Often weeds such as Guinea grass and lantana further increase the risk and impact of fire, carrying hotter fires further and causing further damage to the canopy. Common weeds of the coastal dunes are listed in Table I.2.

Image of foredune erosion caused through uncontrolled vehicle access, Facing Island, Gladstone.

Ten common weed species

Table 8

Ten common weed species of coastal foredunes and beaches

Common name	Scientific name	Declaration status in QLD
Mossman River grass	*Cenchrus echinatus*	Environmental (not declared)
Guinea grass	*Megathyrsus maximux var.maximus*	Environmental (not declared)
Red natal grass	*Melinis repens*	Not declared
Siratro	*Macroptilium atropurpureum*	Not declared
Corky passion vine	*Passiflora suberosa*	Not declared
Cobblers pegs	*Bidens pilosa*	Not declared
Mother of millions	*Bryophyllum spp*	Class 3
Silverleaf sunflower	*Helianthus argophyllus*	Not declared
Painted spurge	*Euphorbia cyathophora*	Environmental (not declared)
Lantana	*Lantana camara*	Class 3 WONS

Coastal foredunes and beaches are at the interface between the marine and terrestrial environments and are natural zones for erosion and deposition. Many beaches are primarily depositional beaches and they may become a place for pollutants and marine debris to accumulate. Marine debris is one of the key threatening processes for marine wildlife under the EPBC Act. Plastics can remain in the environment for millennia and can pose a repeated threat if they are regularly cycled back into the marine environment as a result of wave action and beach erosion.

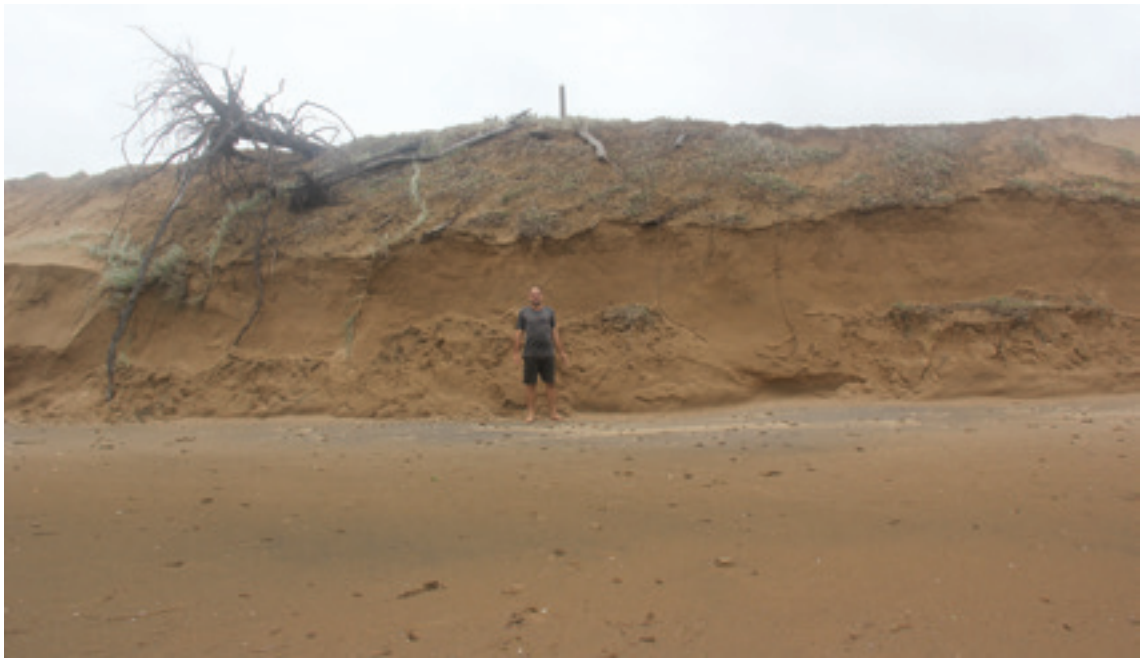
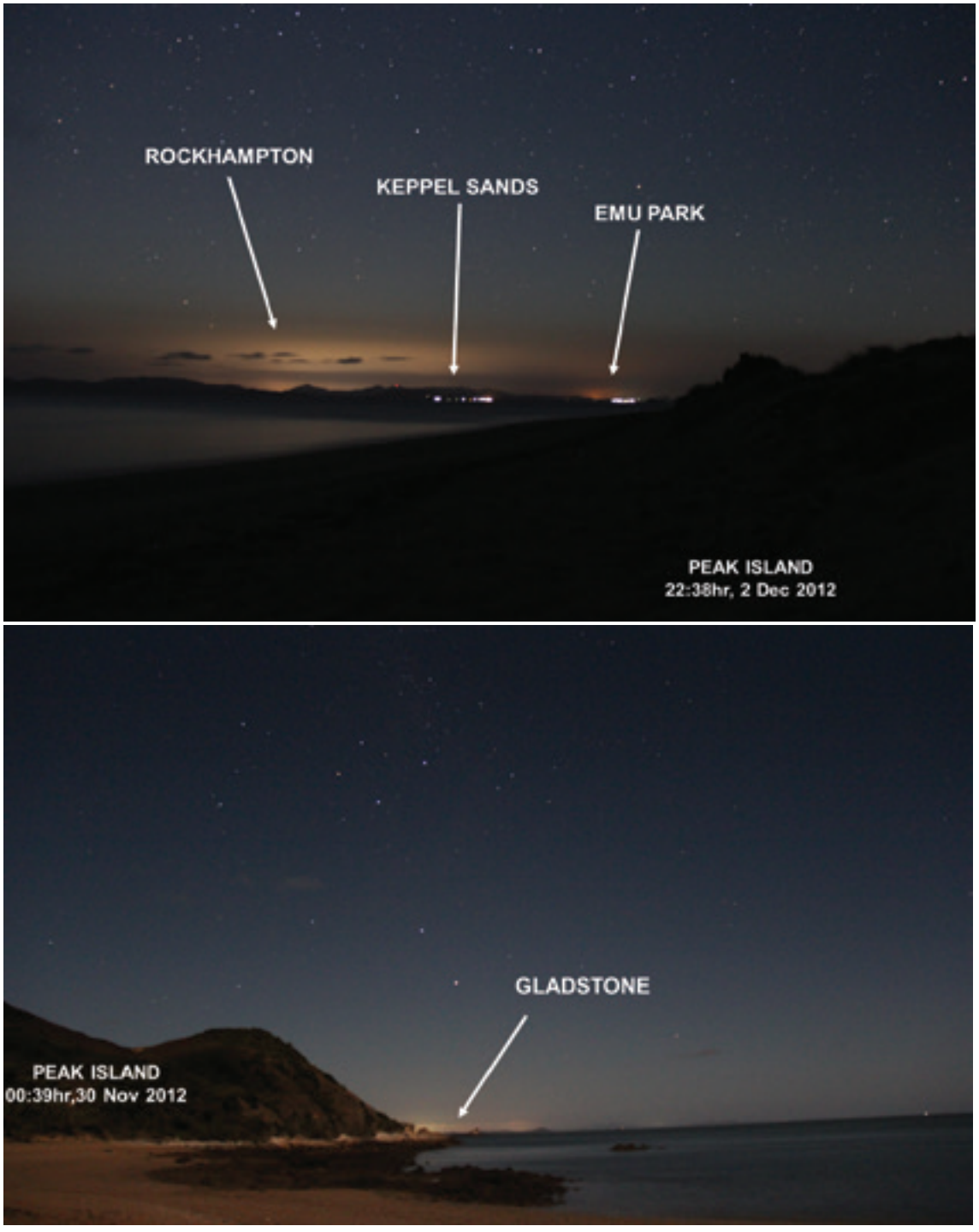


Image of storm erosion on Curtis Island's Main Beach, Southend.

Marine and coastal environments are popular for recreation, which also leads to problems with littering and debris from lost recreational and commercial fishing gear. Noise and light impacts may also affect native animals that use the beaches and foredunes. Coastal lighting can impact marine turtles, and vehicle noise and lights on beaches may disturb coastal birds. Uncontrolled dogs, cats and introduced foxes may also impact coastal bird and marine turtle breeding. It is also important to remember the coastal zone is the area most likely to be impacted should there be a major oil or chemical spill from shipping accessing coastal ports.



Images of light pollution from Peak Island (a flatback turtle nesting beach) in the Keppel Island group. Left: Keppel Sands is approximately 15km west across the bay and Rockhampton is approximately 40km west inland from Peak Island. Right: Gladstone is approximately 60km south-east of Peak Island.

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for project sites in coastal foredunes and beach ecosystems.

Restoration techniques for coastal foredunes and beach

Monitoring biodiversity	A. Photographic monitoring B. Ecological monitoring
Weed control	B. Manual – pulling, grubbing C. Biocontrol – grazing, bugs and fungi, groundcover competition A. (Limited) Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
Erosion control	B. Seeds and plants D. Coconut fibre logs or hay bales E. Fencing – silt, dune, exclusion F. Woody debris G. Geofabrics
Revegetation	B. Direct seeding - hydromulching, seed bombing C. Natural regeneration D. Deep-stem planting E. Cuttings and transplants
Litter reduction	A. Urban litter and marine debris survey G. Cigarette butt bins H. Tangler bins
Pest animal control	A. Nest protection – turtles B. Traps C. Baiting D. Fumigation
Homes for native wildlife	A. Hollow logs B. Wildlife boxes

> marine debris is one of the key threatening processes for marine wildlife

Coastal beach scrub and headland

This chapter describes common coastal beach scrub and headland ecosystem features, typical threats and pressures. It provides guidance on recommended restoration activities suited to coastal beach scrub and headland ecosystems.

Ecosystem description

Central Queensland's coastal dune systems are host to a nationally recognised, critically endangered habitat in the form of coastal beach scrubs. Known alternatively as littoral rainforest, and semi-evergreen vine thickets, beach scrubs are a diverse habitat of dry rainforest species occupying the swales behind the foredunes of a number of Central Queensland beaches. Often a similar plant assemblage is also associated with headlands within the region; however, these plants are generally wind-sheared and stunted, especially in more exposed locations.

Coastal beach scrubs are typified by a closed canopy often no more than 6 to 10 metres in height, a variably dense shrub layer often featuring spiny or coarse leaved species, and a very sparse groundcover layer. Some twining and climbing vines and some epiphytic species such as orchids may be present.

Images of beach scrub behind the strand at Canoe Point Reserve, Tannum Sands.

Recommended plant species

Table 9

Recommended plant species for coastal beach scrubs and headlands.

Common name	Botanical name	Mature height	Strata
Burdekin plum	*Pleigonium timorense*	8–10 m	Tree
Tuckeroo	*Cupaniopsis anarcardioides*	5–8 m	Tree
Canary beech	*Polyalthia ntidissima*	6 m	Tree
Hickory wattle	*Acacia disparrima subsp. disparrima*	6–8 m	Tree
Sticky hop bush	*Dodonea viscosa*	2–3 m	Shrub
Wild prune	*Pouteria sericea*	1–2 m	Shrub
Currant bush	*Carissa ovata*	2–3 m	Shrub
Chain fruit	*Alyxia spicata*	1–3 m	Shrub
Native jasmine	*Jasminum didymium/simplicifolium*	0.7m (shrub)	Shrub/climber

Images of beach scrub behind the strand and on cliffs and headland at Haven Beach, Emu Park.

Threats and pressures

Threats to coastal beach scrubs and headland ecosystems are similar to those described for coastal foredunes. Human interaction such as significant clearing for development, recreation and aesthetically pleasing views of the ocean has degraded major areas of beach scrub throughout Australia. Uncontrolled access from vehicles, pedestrian and stock also dissects habitat patches, opening them to erosion and weed infestation.

Weeds that impact the beach scrubs and headlands are similar to those that impact foredune ecosystems, but due to the more sheltered nature and greater levels of nutrients present, infestations may be more extensive. Beach scrubs are not fire tolerant and invasive species such as Guinea grass and lantana can contribute to greater fuel loads and hotter fires, which can severely damage these ecosystems. Once the canopy of a beach scrub is opened up it may allow invasion by non-native grasses and lead to further damage during fires. Species that are drought-tolerant such as prickly pear and mother of millions are often prominent at these sites.

Ten common weed species

Table 10

Ten common weed species of coastal beach scrubs and headlands.

Common name	Scientific name	Declaration status in QLD
Mossman River grass	*Cenchrus echinatus*	Environmental (not declared)
Guinea grass	*Megathyrsus maximux var.maximus*	Environmental (not declared)
Red natal grass	*Melinis repens*	Not declared
Siratro	*Macroptilium atropurpureum*	Not declared
Corky passion vine	*Passiflora suberosa*	Not declared
Cobblers pegs	*Bidens pilosa*	Not declared
Mother of millions	*Bryophyllum spp.*	Class 3
Prickly pear	*Opuntia spp.*	Class 3
Painted spurge	*Euphorbia cyathophora*	Environmental (not declared)
Lantana	*Lantana camara*	Class 3 WONS

Image of mother of millions, a common invasive weed of degraded coastal ecosystems. Note the small plantlets capable of developing into mature plants along the leaf margins.

Areas of beach scrub are often used for illegal dumping and may also capture windblown debris and rubbish from the exposed foredunes. Rising sea levels, increased storm intensity and prolonged droughts, as expected results of climate change, are also likely to have negative impacts on these habitats. Rising sea levels may allow saltwater intrusion into the groundwater, leading to increased erosion and also contributing to greater impacts from storm events. This may cause physical damage and salt scour to beach scrub habitats. Prolonged drought may also alter the ecosystem's structure, increase susceptibility to fire and retard natural regeneration.

Image of saltwater incursion and subsequent fires have killed the larger trees and destroyed beach scrub elements, Canoe Point, Tannum Sands.

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for coastal beach scrubs and headlands project sites.

Restoration techniques for coastal beach scrubs and headlands

Monitoring biodiversity	A. Photographic monitoring B. Ecological monitoring
Weed control	B. Manual – pulling, grubbing C. Biocontrol – grazing, bugs, fungi, groundcover competition A. (Limited) Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
Erosion control	B. Seeds and plants C. Rock D. Coconut fibre logs or hay bales E. Fencing – silt, dune, exclusion F. Woody debris G. Geofabrics
Revegetation	A. Tubestock planting B. Direct seeding - hydromulching, seed bombing C. Natural regeneration D. Deep stem planting E. Cuttings and transplants
Litter reduction	A. Urban litter and marine debris survey D. ocks
Pest animal control	B. Traps C. Baiting D. Fumigation
Homes for native wildlife	A. Hollow logs B. Wildlife boxes

> once the canopy of a beach scrub is opened up it can allow invasion by non-native grasses

Marine plain

This chapter describes common marine plain ecosystem features, typical threats and pressures and provides guidance on recommended restoration activities suited to marine plain ecosystems.

Ecosystem description

Marine plains have often been regarded as wasteland, suitable only for dumping waste or being filled and reclaimed for development. These areas are usually characterised by extensive bare flats, infrequently inundated by high tides. The vegetation is often coarse, salt-tolerant grasses and herbs or forbs. Trees and shrubs are generally lacking on marine plains, although mangroves may be a feature along drainage channels and watercourses, as well as adjacent to the strandline. Soils are often heavy, highly saline and waterlogged. Saline and brackish swamps may feature in low-lying areas.

Images of marine plains Left: Marine plain, north of Gladstone. Right: Marine couch grassland on a marine plain, also north of Gladstone.

Recommended plant species

Table 11

Recommended plant species for marine plain ecosystems

Common name	Botanical name	Mature height	Strata
Marine couch	*Sporobolus virginicus*	0.3 m	Groundcover - grass
Prickly couch	*Zoysia macrantha*	0.3 m	Groundcover - grass
Rush	*Juncus polyanthemus*	1.2 m	Groundcover – rush
Sea purslane	*Sesuvium portulacastrum*	0.2 m	Groundcover –herb
Samphire	*Halosarcia indica*	0.4 m	Groundcover –herb
Beaded glasswort	*Sarcocornia quinqueflora*	0.5 m	Groundcover -herb
Seablite	*Suaeda australis*	0.3 m	Groundcover -herb
Ruby saltbush	*Enchylaena tomentosa*	0.75 m	Groundcover - herb
Bare twig-rush	*Baumea juncea*	0.9 m	Groundcover - rush
Rusty fringe-rush	*Fimbristylis ferrugeana*	0.6 m	Groundcover - rush

Images of salt tolerant plants of marine plains. Left: ruby saltbush (Enchylaena tomentosa). Right: samphire (Haloserica spp.).

Threats and pressures

Most threats to marine plains arise from human interactions. Marine plains have been repeatedly filled, reclaimed or used as dumping grounds for urban and industrial waste. In some areas, the marine couch grasslands were grazed, as seen in Figure III.3, which shows the remnants of an old stock fence. In some areas on the lower reaches of the Fitzroy River floodplain, marine plains are often converted into ponded pastures using levees and embankments to prevent saltwater intrusion and allowing ponded pasture grasses to grow. Often these ponded pasture species have established and become weed species. Bunds and levee banks alter stream flows and can affect patterns of sedimentation and deposition, upset nutrient flows and impede fish migrating to and from saltwater environments, thus adversely affecting breeding and repopulation of waterholes and lagoons.

In the Gladstone region, large areas of marine plain have been converted into retention basins and sedimentation ponds for containing or storing industrial waste and effluent associated with industry. Large areas have also been filled and reclaimed for development, especially for industrial and commercial purposes. Disturbing the substrates of marine plains often exposes acid sulfate soils, which results in acidic drainage when exposed to the atmosphere.

Using marine plains as dumping grounds and as industrial effluent ponds has created some issues of both aesthetic and insidious pollution. Pollution may include industrial waste leachate, especially if containment ponds have not been constructed to acceptable environmental standards. Failure of pond bunds due to environmental events such as flooding storm damage and slumping walls can cause waste to directly leak into the environment. Failure of the Western Basin dredge disposal area's bund was partly responsible for Gladstone Harbour's turbidity issues.

Increased legislation and environmental monitoring has been implemented to minimise pollutants entering the marine environment and, as such, these containment basins, effluent ponds and sediment traps are designed to protect the marine environment. As marine plains are seen to be of little value, they are often used for this purpose.

Images of marine plain used for storing industrial wastes (fly ash) and as effluent settlement ponds, near Reg Tanner Coal Terminal, Gladstone.

Images of marine plain used for storing industrial wastes (fly ash) and as effluent settlement ponds, near Reg Tanner Coal Terminal, Gladstone.

Marine plains are a harsh environment and few weed species are found there. Broad-leaved pepper tree (*Schinus terebinthifolius*) may be associated with drainage lines, and some introduced grasses may be found, especially in areas of less saline influence. In areas where ponded pasture has been established, several exotic grass species such as hymenachne (*Hymenachne amplexicaulis*) and para grass (Urochloa mutica) may predominate, altering fire regimes and impacting native vegetation.

Recommended restoration activities

This section is from the Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for marine plain project sites.

Restoration techniques for marine plains

Monitoring biodiversity	A. Photographic monitoring B. Ecological monitoring
Weed control	B. Manual – pulling, grubbing
Erosion control	A. Battering of slope B. Seeds and plants C. Rock D. Coconut fibre logs or hay bales E. Fencing – silt, dune, exclusion F. Woody debris G. Geofabrics
Revegetation	C. Natural regeneration E. Cuttings and transplants
Pollution mitigation devices	A. Urban litter and marine debris survey B. Biofiltration C. Gross pollutant traps D. Socks
Pest animal control	B. Traps C. Baiting D. Fumigation
Homes for native wildlife	A. Hollow logs C. Fish passage D. Fish hotels

Wetlands

This chapter describes common wetland ecosystem features, typical threats and pressures and provides guidance on recommended restoration activities suited to wetland ecosystems.

Ecosystem description

Wetlands are essential elements of our landscape. They bridge terrestrial and aquatic ecosystems and provide habitat for important commercial species, migratory birds and a wide range of other native animals. They act as filters, providing clean water, and help mitigate against flooding, storm surges and wave action. They also act as a carbon sink, storing atmospheric carbon dioxide in plant material, making them important in mitigating against the effects of anthropogenic climate change. They are also important in nutrient cycling.

Images of two different wetland ecosystems north of Gladstone. Left: A wetland dominated by sedges. Right: A tea tree-dominated wetland.

Wetlands may range from seasonally inundated areas to areas that permanently hold water. Water may range from fresh through brackish to saline, depending on proximity and connectivity with the coast, prevailing soil type and presence of salinity in rising groundwater.

Vegetation in wetlands may act as an important filter, pulling harmful heavy metals and other toxic chemicals from the water and sequestering them in sediments. Depending on the water's salinity, wetlands may be dominated by grasses, sedges and rushes. Melaleucas are often the dominant trees as many can tolerate being seasonally inundated. Saline wetlands are dominated by saltmarsh plants and mangrove species can also feature prominently. In tropical tidal systems, mangroves become the dominant species. Wetland ecosystems such as mangroves play an important role in stabilising coastal landscapes, trapping sediments, absorbing impacts of wave action and storm surges and protecting against flooding. They are also important nursery habitats for fish and invertebrates such as prawns and crabs.

Recommended plant species

Table 12

Recommended plant species for wetland ecosystems

Common name	Botanical name	Mature height	Strata
Common mat-rush	*Lomandra longifolia*	1.0 m	Groundcover
Jointed twig-rush	*Baumea articulata*	1.0 m	Groundcover
Bunchy sedge	*Cyperus polystachyos*	0.6 m	Groundcover
Sedge	*Lepironia articulata*	2.0 m	Groundcover
River lily/field lily	*Crinum pedunculatum/angustifolium*	1.0 m	Groundcover
Swamp mahogany	*Eucalyptus robustus*	30 m	Tree
Swamp she-oak	*Casuarina glauca*	20 m	Tree
Paper-barked tea tree	*Melaleuca quinquenervia*	25 m	Tree
Broad-leaved tea tree	*Melaleuca viridiflora*	18 m	Tree
Weeping tea tree	*Melaleuca leucadendra*	25 m	Tree

Threats and pressures

Wetlands have traditionally been viewed as areas for mosquitoes and sandflies to breed. As such, they have often been cleared, drained or filled, or converted into fast-draining concrete-lined culverts to ensure water does not sit for long periods and allowing pests to breed there. Obviously, this conversion to drains removes the capacity of wetlands to provide the services of sediment retention, water filtration, and flood and storm surge protection. Their use as wildlife habitat and nursery areas for species is also severely impacted.

The presence of reliable moisture makes wetlands susceptible to invasion by a large range of weed species. In urban areas, dumping garden wastes in wetland areas often causes invasion by garden escapees, such as broad-leaved pepper tree (*Schinus terebinthifolius*), Singapore daisy (*Sphagneticola trilobata*) and morning glory vines (*Ipomea spp*).

In areas of permanent water, Weeds of National Significance such as hymenachne (*Hymenachne amplexicaulis*), an introduced ponded pasture grass; water hyacinth (*Eichornia crassipes*), and salvinia (*Salvinia molesta*) may become severe weeds. Often these species will completely cover the water surface, choking out native plant species and preventing light penetration. They can remove oxygen from the water when they die and decay.

Images of different wetlands. Left: Wetland on the Fitzroy River floodplain choked with water hyacinth. Right: A freshwater wetland near Gladstone smothered by introduced grasses.

Ten common weed species

Table 13

Ten common weed species of wetland ecosystems

Common name	Scientific name	Declaration status in QLD
Hymenachne	Hymenachne amplexicaulis	Class 3 WONS
Guinea grass	Megathyrsus maximux var.maximus	Environmental (not declared)
Para grass	Urichloa mutica	Environmental (not declared)
Water hyacinth	Eichornia crassipes	Class 3 WONS
Salvinia	Salvinia molesta	Class 3 WONS
Johnson grass	Sorghum halapense	Environmental (not declared)
Rubber vine	Cryptostegia grandiflora	Class 3 WONS
Singapore daisy	Wedelia trilobata	Class 3
Broad-leaved pepper tree	Schinus terebinthifolius	Class 3
Lantana	Lantana camara	Class 3 WONS

In areas not regularly inundated, lantana and rubber vine may become established. Introduced grasses such as para grass and Johnson grass may dominate in wetter areas, and Guinea grass may dominate in drier areas. These species can compete with native species, smother native seedlings and alter fire regimes, leading to canopy damage in fire events.

Wetlands may also be susceptible to dumping of rubbish and contaminated fill, industrial waste outflows and farm effluent. In small amounts, and with less toxic substances, wetlands may be able to filter pollutants from the water but in large doses, and with highly toxic effluent, wetlands are unable to cope. Increased nutrient enrichment from fertiliser run-off or farm effluent can seriously impact wetlands by triggering rapid growth of aquatic plants (especially weed species) or algae, which removes oxygen from the water body as it dies and decomposes. This may cause fish kills and water bodies to stagnate, accelerating the natural aging process of wetlands (eutrophication).

Contaminated groundwater may carry pollutants, industrial leachates and increased salinity, and can infiltrate wetlands. Slower water flows through wetlands may also result in sedimentation, which can smother aquatic plants. In many modern urban developments, wetlands are constructed to act as sedimentation basins and biofilters. This is a great leap forward in managing urban run-off and applying natural systems to help mitigate pollution, but it these wetlands must be regularly maintained for them to function effectively. This may include thinning vegetation and removing built-up sediments.

Rising sea levels caused by climate change are expected to alter connectivity of wetlands with marine systems. This may lead to a greater incursion of saltwater into freshwater ecosystems. Prolonged droughts and more intense storms and floods may also compromise the natural functioning of wetland habitats.

Image of dumped oil drum leaking waste oil, Wapentake Wetlands, South Trees, Gladstone.

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for wetland project sites.

Restoration techniques for wetlands

Monitoring biodiversity	A. Photographic monitoring B. Ecological monitoring C. Water quality monitoring
Weed control	B. Manual – pulling, grubbing C. Biocontrol – grazing, bugs and fungi, groundcover competition A. (Limited) Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
Erosion control	A. Battering of slope B. Seeds and plants C. Rock D. Coconut fibre logs or hay bales E. Fencing – silt, dune, exclusion F. Woody debris G. Geofabrics
Revegetation	A. Tubestock planting C. Natural regeneration D. Deep-stem planting
Pollution mitigation devices	A. Urban litter and marine debris survey B. Biofiltration C. Gross pollutant traps D. Socks
Pest animal control	A. Nest protection – turtles B. Traps C. Baiting D. Fumigation E. Electrofishing
Homes for native wildlife	A. Hollow logs B. Wildlife boxes C. Fish passage D. Fish hotels

Semi-evergreen vine thicket

This chapter describes common semi-evergreen vine thicket (dry rainforest) ecosystem features, typical threats and pressures. It also provides guidance on recommended restoration activities suited to semi-evergreen vine thicket ecosystems.

Ecosystem description

Semi-evergreen vine thickets (SEVT), alternatively known as dry rainforest, vine scrub or softwood scrubs are listed as an endangered ecosystem under the EPBC Act. These ecosystems occur from the littoral dune systems through to moister gullies and protected hillsides of the arid interior. It is believed they are the remnants of a much wider plant assemblage that once covered Australia when it was much wetter, and prior to firestick farming methods employed by Indigenous Australians. As Australia gradually drifted northwards and dried out, coupled with regular burning practices, the fire-adapted species gradually became dominant and formed the dry eucalypt and acacia woodlands we associate with typical Australian bush. Large-scale mechanised clearing for agriculture since the 1960s has further fragmented SEVT ecosystems. Small remnant pockets of SEVT remain in sheltered areas away from impacts of fire. SEVT ecosystems are dominated by fire-sensitive communities, often of softwood trees and contain many species allied to those of wetter rainforests. They also include many rare and endangered species, some representing ancient floristic assemblages.

SEVT ecosystems are characterised by a closed canopy, though often with emergent species such as crows ash (*Flindersia australis*), bottle tree (*Brachychiton spp.*) and poop pine (*Araucaria cunninghamii*), depending on the location. There is a dense, often spiny, shrub layer that occasionally comprises an upper and lower shrub layer, as well as a very sparse understorey of grasses, lilies or ferns. There is often a marked litter layer covering the ground. Trees may be semi-deciduous, especially in drier periods. Climbing vines and lianas may be present, though generally only a moderate number of species are represented. SEVT is considered to be a graded ecosystem, with habitats in the north having a different species assemblage than those in the central and southern extremities of the Brigalow Belt Bioregion.

Image of semi-evergreen vine thicket, Boyne Valley, Central Queensland.

Excluding fire and removing grazing pressure will often help adjacent woodland areas recolonise, especially if judicious weed control is practised. Shade can exclude several of the common weeds of SEVT. If a canopy of SEVT species can be developed, weeds may often fail to thrive. For example, although lantana is a vigorous invasive weed of disturbed sites, streamlines and margins, it is not usually found under the canopy of developed rainforest, dry scrub or intact riparian communities. However, some weeds, such as broad-leaved pepper tree and coral berry (*Rivina humilis*) can tolerate shade and invade areas of SEVT set aside for natural regeneration.

Allowing natural regeneration and shading to out-compete weeds is a slow process and may take many years; however, this approach may be highly cost-effective and may only require supplementary plantings to add species diversity to existing areas or to fill-in with species representative of strata that have not naturally regenerated. This method may require selective weed control to create a mosaic of suitable environmental niches for recolonisation and will require fires to be excluded for a prolonged timeframe.

Recommended plant species

Table 16

Recommended plant species for SEVT ecosystems

Common name	Botanical name	Mature height	Strata
White cedar	*Melia azedarach*	8–10 m	Small to medium tree
Rusty fig	*Ficus rubiginosa*	12–15 m	Tree
Hickory wattle	*Acacia disparrima*	12 m	Tree
Sandpaper fig	*Ficus opposita*	8 m	Small tree
Red Ash	*Alphitonia excelsa*	5 m	Shrub or small tree
Bat wing coral tree	*Erythrinia vespertilio*	8 m	Small to medium tree
Currant bush	*Carissa ovata*	2 m	Shrub
Tuckeroo	*Cupaniopsis anarcardioides*	10–12 m	Small to medium tree
Lime berry	*Micromelum minutum*	7 m	Small tree
Wallaby apple	*Pittosporum spinescens*	1–2 m	Spiny shrub

Threats and pressures

SEVT clearing may have originated with firestick farming methods of Indigenous Australians, in efforts to create mosaics of regenerating habitats to encourage game. However, it is estimated that the pre-clearing extent of SEVT in the Brigalow Belt Bioregion in Queensland was over 880,000 ha. Extensive clearing of this ecosystem has occurred since European settlement, especially since the 1960s when large-scale clearing was conducted to create extensive grazing and cropping lands. Anecdotal evidence suggests SEVT was cleared preferentially to Brigalow (*Acacia harpophylla*) due to its lack of tendency to re-sprout from rootstock. Also, SEVT soils were thought to be more favourable for agriculture. Remaining SEVT is highly fragmented. It often has relatively small patch size, and connectivity between patches is often poor. Invasion by introduced weeds, especially introduced pasture species and lantana, increases the risk of wildfire, especially as surrounding land may be regularly burnt as a management practice. Fire impacts are greatest in SEVT that is already disturbed through grazing, clearing of breaks and fence lines, and in areas infested with weed species.

Intact SEVT ecosystems are less likely to be impacted by grazing stock than previously disturbed sites, though browsing by black-striped wallabies (*Macropus dorsalis*) is a significant impact on regenerating SEVT vegetation. SEVT was intentionally cleared in some areas as it was noted habitat for this wallaby, which is considered a pest of agricultural crops.

SEVT clearing may still occur for fire breaks, fence lines, roads and rail corridors and also for open-cut or surface mining. Any SEVT clearing tends to cause greater ecosystem fragmentation and allows weed species to invade.

Common weeds of SEVT are generally introduced pasture grasses and woody weeds such as lantana and rubber vine. The main impacts weeds have on SEVT ecosystems are increasing the fire risk, which alters fire frequency and intensity, and out-competing regrowth of SEVT species.

Pollution, apart from scattered dumping, and possible impacts from a changing climate are not considered major impacts on SEVT ecosystems. However, climate impacts such as prolonged drought may adversely affect the capacity for SEVT to regenerate. Drier conditions may also create higher intensity fires with damaging effects on SEVT.

Image of cats claw creeper, a large woody vine that climbs and creeps aggressively smothering native vegetation.

Ten common weed species

Table 17

Ten common weed species of SEVT ecosystems

Common name	Scientific name	Declaration status in QLD
Cats claw creeper	*Macfadyena unguis-cati*	Class 3 WONS
Green panic	*Megathyrsus maximus var. pubiglumis*	Environmental (not declared)
Velvet tree pear	*Opuntia tomentosa*	Class 3 WONS
Rubber vine	*Cryptostegia grandiflora*	Class 3 WONS
Lantana	*Lantana camara*	Class 3 WONS
Glycine	*Neonotia wightii*	Environmental (not declared)
Coral berry	*Rivina humilis*	Environmental (not declared)
Brazilian nightshade	*Solanum seaforthianum*	Environmental (not declared)
Broad-leaved pepper tree	*Schinus terebinthifolius*	Class 3
Prickly pear	*Opuntia stricta*	Class 3 WONS

> any SEVT clearing tends to cause greater ecosystem fragmentation and allows weed species to invade

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for wetland project sites.

Restoration techniques for wetlands

Monitoring biodiversity	A. Photographic monitoring B. Ecological monitoring
Weed control	B. Manual – pulling, grubbing C. Biocontrol – grazing, bugs and fungi, groundcover competition A. (Limited) Chemicals – cut stump, basal bark, spraying, splatter gun, pellets E. (Limited) Mechanical – brushcutting, slashing, dozing, stick raking or blade ploughing.
Erosion control	B. Seeds and plants C. Rock D. Coconut fibre logs or hay bales E. Fencing – silt, dune, exclusion F. Woody debris G. Geofabrics
Revegetation	A. Tubestock planting B. Direct seeding - hydromulching, seed bombing C. Natural regeneration E. Cuttings and transplants
Litter reduction	A. Urban litter and marine debris survey D. Socks
Pest animal control	B. Traps C. Baiting D. Fumigation
Homes for native wildlife	A. Hollow logs B. Wildlife boxes

> the main impacts weeds have on SEVT ecosystems are increasing the fire risk

Eucalypt forest and woodland

This chapter describes common eucalypt forest and woodland ecosystem features, typical threats and pressures. It provides guidance on recommended restoration activities suited to eucalypt forest and woodland ecosystems.

Ecosystem description

Open eucalypt forest and open eucalypt woodland is the predominant ecosystem type over large areas of Australia. As the name suggests, the major vegetation strata is dominated by *Eucalyptus/ Corymbia* species. Depending on the moisture regime, soil type and fire frequency, different eucalypt species may dominate different habitats. Canopy density and canopy height determine whether an ecosystem is listed as forest or woodland; forest is denser and taller than woodland. Canopy species composition is typically low; less than five species.

Most eucalypt-dominated ecosystems are adapted to fire; this accounts for their widespread dominance. It is believed Aboriginal burning, or firestick farming, was sufficiently widespread and frequent enough to bring about dramatic changes in the plant assemblages that once dominated Australia. Regular burning removed fire-sensitive softwood species and replaced them with fire-tolerant hardwoods such as eucalypts and acacias. Aided by a drying climate, as Australia slowly drifted northwards this regular burning resulted in the dryland ecosystems we recognise today.

The canopy density, soil fertility and available rainfall will affect the composition of understorey layers. In more fertile areas with higher rainfall, a quite dense shrub or small tree layer may form, which grades into sparser, shorter dryland-adapted shrub species as rainfall and soil fertility fall or fire frequency increases. In areas that are frequently burnt, grass and herbs dominate the understory and shrubs are infrequent.

Images of different eucalypt forests Top: Open eucalypt woodland on hill slopes at Beecher, near Gladstone. Bottom left and bottom right: Open Eucalypt forest, Kroombit Tops National Park. (Images courtesy Conservation Volunteers Australian, Gladstone)

Recommended plant species

Table 18

Recommended plant species for the open eucalypt forest and woodlands.

Common name	Botanical name	Mature height	Strata
Moreton Bay ash	*Corymbia tesselaris*	30 m	Tall tree
Lemon-scented gum	*Corymbia citriodora*	30–35 m	Tall tree
Red bloodwood	*Corymbia erythrophloia*	12–15 m	Small to medium tree
Pink bloodwood	*Corymbia intermedia*	15–30 m	Medium to tall tree
Queensland blue gum	*Eucalyptus tereticornis*	30 m	Tall tree
Forest she-oak	*Allocasuarina torelosa*	10–15 m	Small to medium tree
Sandpaper fig	*Ficus opposita*	8–12 m	Small tree
Native hibiscus	*Hibiscus divaricatus*	2–3 m	Shrub
Coffee bush	*Breynia oblongifolia*	2–3 m	Shrub
Kangaroo grass	*Themeda triandra*	1 m	Grass

Elevated habitat

Elevated eucalypt habitat is ideal for cycads and grass tree, which are restricted in distribution in the area, confined to upland regions and dominated by two cycad species endemic to the Central Queensland region: Cycas megacarpa and Marlborough blue (*Cycas ophiolitica*). Both are listed species under the EPBC Act. Queensland has a large representation of cycad species with 13 per cent of the world's cycad species, and 41 of Australia's 74 cycad species occurring within the region. Other cycads in the wider area include Byfield fern (*Bowenia serrulata*), which is endemic to the Byfield area, zamia palm (*Macrozamia miquelii*), which is generally a coastal plant and with a wider distribution than the Byfield fern, and the listed *Macrozamia platyrhachis* from the Blackdown Tablelands. A recovery plan exists for a number of the cycads including Marlborough blue *C. megacarpa* and *M. platyrhachis*.

Images of cycads and grass tress in eucalypt forests. Left: Cycad habitat on the slopes of Kroombit Tops National Park. Right: Grass tree understory in a patch of peri-urban eucalypt woodland, Kirkwood, Gladstone.

Cycads are a slow growing, long lived species. They are representative of an ancient flora dominant during the reign of the dinosaurs. Individual cycad plants are either male or female and both produce cones. Seeds undergo a delayed fertilisation process and germination can be delayed for up to nine months after seed falls from the cones. Germination may be erratic. Mature plants are relatively fire-tolerant but seeds and juvenile plants are often killed by fire. Cycads are often representative of the understorey within eucalypt woodland or open forest. They may also be associated with grass trees (*Xanthorrhoea spp.*).

Cycads are capable of fixing atmospheric nitrogen and this may actively benefit soil fertility in areas where they predominate. *C. ophiolitica* also appears to do best in heavy red clays over serpentinite — a unique landform in the Marlborough area, north of Rockhampton. Seed dispersal appears to be a major factor that limits the distribution of cycad species.

Images of elevated eucalypt forest plants. Left: Cycad understorey in dense wet eucalypt forest, Kroombit Tops National Park. Middle: Female cone of Macrozamia miquelii, Tondoon Botanic Gardens, Gladstone. Right: Cycas megacarpa female cone, Kroombit Tops National Park.

Recommended elevated plant species

Table 19

Recommended elevated plant species

Common name	Botanical name	Mature height	Strata
None recorded	*Cycas megacarpa*	5 m	Understorey
Marlborough blue	*Cycas ophiolitica*	2 m	Understorey
Zamia palm	*Macrozamia miquelii*	2 m	Understorey
None recorded	*Macrozamia serpentine*	2 m	Understorey

> cycads are capable of fixing atmospheric nitrogen and this may actively benefit soil fertility

Threats and pressures

Human impacts on eucalyptus forests and woodlands include forestry activities such as timber extraction for quality hardwoods for building; rough-sawn timbers for railway sleepers; and posts for fencing, wharves and mine props. In some areas, large forest reserves were felled for wood chip to manufacture paper products. Human impacts also include clearing for agriculture and grazing, road and residential development and mining and industrial activities.

In grazing areas, thinning trees to encourage grass growth and too frequent burning simplifies the ecosystem and leads to a sparse and open, grassy landscape with generally mature trees, little regeneration and a lack of shrub species. Over-grazing these habitats by hard-hoofed animals compacts and degrades soil. This can lead to soil erosion especially in marginal areas under excessive grazing pressure. Soil degradation can lead to excessive use of artificial fertilisers and contributes to salinity of rising groundwater.

A large number of Weeds of National Significance are associated with open eucalypt forest and woodland ecosystems as many are associated with the grazing and pastoral industry through introduction as fodder crops, or as contaminants of livestock shipments, feed, grain or fodder. Further weed spread may be associated with vehicle movements associated with surveying, mining and development.

Grasses and woody weed species may alter fire regimes and fire intensity. This may, in turn, alter habitat structure and prevent shrub and tree species regenerating, allowing weed species dominate a wider area. Unpalatable weeds may create greater grazing pressure on native species and hence increase vegetation loss, leading to further erosion issues.

Ten common weed species

Table 20

Ten common weed species of open eucalypt forest and woodland ecosystems

Common name	Scientific name	Declaration status in QLD
Buffel grass	*Pennisetum ciliare*	Environmental (not declared)
Guinea grass	*Megathyrsus maximux var.maximus*	Environmental (not declared)
Giant rats tail grasses	*Sporobolos pyramidalis/natalensis*	Class 3
Chinee apple	*Ziziphus mauritiana*	Class 3
Prickly acacia	*Acacia nilotica*	Class 3 WONS
Leucaena	*Leucaena leucocephala*	Environmental (not declared)
Rubber vine	*Cryptostegia grandiflora*	Class 3 WONS
Parkinsonia	*Parkinsonia aculeate*	Class 3 WONS
Parthenium	*Parthenium hysterophorous*	Class 3 WONS
Lantana	*Lantana camara*	Class 3 WONS

Controlling many of these species is time consuming, costly and has economic impacts in terms of lost productivity, increased efforts in mustering stock and through downstream impacts such as siltation of dams, waterways and wetlands.

Pollution of open forests is generally related to littering, illicit dumping and impacts from increased fertilisation of adjoining agricultural land or pastures. This can result in nutrient enrichment of soils, and increased salinity levels in groundwater and watercourses. In areas impacted by mining and development, dust, noise and light pollution may be significant and vegetation adjacent to major roadways may be impacted by exhaust fumes and dust from vehicles.

Climate change impacts may include exposure of open forests to more prolonged droughts, leading to more intense fires, which can scorch the canopy and alter the species composition. In exposed locations, an increase in storm intensity may damage canopy species.

Possibly the greatest threat to mountainous cycad habitat arises from clearing for land development, mining and agriculture. Due to their low rates of dispersal, populations may be quite localised and isolated from other patches of similar habitat. As cycads are toxic to cattle, selectively poisoning cycads is quite common in grazing areas. Unsuitable fire regimes in areas of cycad habitat may affect recruitment into the population as seeds and seedlings are fire-sensitive. The post-ripening period required for fertilising cycad seeds means fallen seed is vulnerable to fire once it falls from the cone. Hot fires will kill cycad seedlings. Both legal and illegal collecting for nursery and garden specimens is another factor that can contribute to the decline in cycad populations. With a large specimen fetching several hundred dollars in the nursery trade, collecting cycads can be a lucrative business.

It appears that a loss of insect pollinators may have caused the decline in some species and it is possible the mechanism for large seed dispersal has been lost. Studies indicate the seed coat is non-toxic, whereas the seed is toxic. This suggests a seed dispersal mechanism where the seed was eaten whole and voided intact. There are few native vertebrates capable of feeding on the toxic seeds. Aboriginal people used cycad seeds as a food source after the seeds had been prepared through a long leaching process. It is possible that as Aboriginal people have adopted non-traditional foods cycad seeds are no longer being collected and moved around the landscape.

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for eucalypt forest and woodland.

Restoration techniques for eucalypt forests and woodlands

Monitoring biodiversity	A. Photographic monitoring B. Ecological monitoring
Weed control	A. Chemicals – cut stump, basal bark, spraying, splatter gun, pellets B. Manual – pulling, grubbing C. Biocontrol – grazing, bugs and fungi, groundcover competition D. Fire/thermal
Erosion control	A. Battering of slope B. Seeds and plants C. Rock D. Coconut fibre logs or hay bales E. Fencing – silt, dune, exclusion F. Woody debris G. Geofabrics
Revegetation	A. Tubestock planting B. Direct seeding - hydromulching, seed bombing C. Natural regeneration E. (Limited) Cuttings and transplants
Litter reduction	A. Urban litter and marine debris survey B. Socks
Pest animal control	B. Traps C. Baiting D. Fumigation
Homes for native wildlife	A. Hollow logs B. Wildlife boxes

Riparian

This chapter describes common riparian ecosystem features, typical threats and pressures and provides guidance on recommended restoration activities suited to riparian ecosystems.

Ecosystem description

A riparian ecosystem is the vegetation community bordering the banks of waterways, creeks, streams and rivers. It is an important zone as it provides the link between terrestrial and aquatic habitats and is important in water filtration, soil conservation and nutrient cycling, biodiversity conservation and flood mitigation. Riparian zones tend to be relatively narrow bands of vegetation bordering watercourses and because of this, they are prone to edge effects such as weed encroachment and fire impacts. However, often they may be preserved, at least in part, as they are generally unsuited for direct human use due to flooding risk, As a result, they may function as natural corridors between remnant habitats in a fragmented landscape. Birds, bats and both native and introduced mammals use riparian zones to move between habitats. Increasingly, riparian habitat is being recognised for its important ecosystem functions and is often the focus of environmental restoration and revegetation projects.

Images of riparian ecosystem, Double Creek, Calliope.

Riparian plant species tend to have greater moisture requirements than woodland species, are also tolerant of flooding and inundation. Many will actively reshoot from the base if snapped off in large flood events. Studies suggest riparian vegetation occurs only where there is frequent flooding: a one-in-two-, or a one-in-five- yearly flood event. Riparian vegetation commonly has deep, matting root systems that anchor them during floods and additionally hold the bank together under high flow events. Maintaining vegetation along stream banks can be essential to prevent erosion and soil loss. Generally, riparian vegetation has some fire resistance and is reasonably resistant to disturbance. Species are usually reasonably fast growing and efficient colonisers that take advantage of gaps created by large flood events that have removed vegetation. Riparian ecosystems tend to be lusher, grow more densely and are often taller than surrounding habitats due to the more abundant water supply and the richer alluvial soils found along watercourses.

Riparian zones may grade from quite lush gallery (riparian) rainforest in wetter areas such as Byfield, and with palms and rainforest species present, through to quite dry vegetation dominated by woodland species in more arid areas and bordering intermittent watercourses. Mangroves form the predominant riparian vegetation in saline areas of estuaries and river mouths. As birds, fruit-eating bats and many small mammal species use riparian zones as corridors between habitats, there can be diverse fruiting species such as figs (*Ficus spp.)*, Burdekin plum (*Pleiogynium timorense*), Leichardt tree (*Nauclea orientalis*)and lilly pillies (*Syzygium spp.*).

Riparian vegetation also shades the water body, which may reduce in-stream photosynthesis, so pools do not become overgrown with aquatic plant life. Shading may also reduce evaporation rates and the

dappled light reaching the water may help native fish hide from predators. Cooler water bodies are also able to hold more dissolved oxygen and are therefore better habitat for fish and aquatic insects. The presence of tree roots and fallen limbs or trees in a watercourse also provides habitat and refuges for aquatic life.

Images of tree roots and fallen logs providing in-stream woody debris wildlife habitat.

Recommended plant species

Table 21

Recommended plant species for riparian ecosystems

Common name	Botanical name	Mature height	Strata
Common mat-rush	*Lomandra longifolia*	1 m	Groundcover
Sandpaper fig	*Ficus coronate or F. opposita*	12 m	Shrub or small tree
Weeping cabbage palm	*Livistona decora*	15 m	Palm
Swamp she-oak	*Casuarina glauca*	20 m	Salt-tolerant tree
River she-oak	*Casuarina cunninghamiana*	30 m	Tree
Queensland blue gum	*Eucalyptus tereticornis*	40 m	Tree
Creek lilly pilly	*Syzygium australe*	15 m	Tree
Creek bottlebrush	*Callistemon viminalis*	8–10 m	Small tree
Black tea tree	*Melaleuca bracteata*	8–10 m	Small tree
Weeping tea tree	*Melaleuca leucadendra*	20–25 m	Tree

> a riparian ecosystem is the vegetation community bordering the banks of waterways

Typical threats and pressures

Direct threats to riparian zones include clearing bankside vegetation and altered natural drainage features such as straightening and widening of natural streams into culverts and drains. In urban situations natural creeks are often severely modified, and are often concreted, and run through pipes, box culverts and other artificial drainage systems. In these situations, it is probably impossible without serious expenditure and engineering to rehabilitate the system so it functions as a natural stream would. Urban run-off is generally in the form of pulsed flows as there is a predominance of hard surfaces and structures and minimal opportunity for infiltration and slowing flow rates down. This can impact vegetation by subjecting it to scouring rapid flows and minimal infiltration of water into the soil. Fragmented vegetation reduces the resilience and functioning of riparian systems.

In more rural locations, clearing and thinning of riparian zones is commonplace. Riparian vegetation should ideally by a 50 m wide zone stretching from the streamline over the banks to at least the extent of the highest in-stream flows. Grazing and repeated fires can damage the edges of the riparian zone, allowing weed encroachment and further damage from grazing. Weed encroachment often increases fuel loads, creating hotter and more frequent burns. Hotter fires may damage the canopy and kill less fire-resistant species, slowly destroying the riparian ecosystem's integrity.

Weeds of National Significance (WONS) such as rubber vine and cats claw creeper, whose seeds may be spread by wind and water, are common in Central Queensland waterways. Lantana, which is spread by frugivorous birds, also commonly invades riparian zones. These WONS species prefer richer soils and are rapid colonisers of degraded ecosystems. Being woody species, they increase fuel loads and significantly increase fire intensity. Cats claw creeper may also smother large trees and cause them to fall during storms and floods.

Image of fire degraded riparian habitat, Moores Creek, Rockhampton. Note the fire scarring on tree on left.

Image of cats claw creeper smothering riparian vegetation, Double Creek Calliope.

> direct threats to riparian zones include clearing bankside vegetation and altering natural drainage features

Ten common weed species

Table 22

Ten common weed species of riparian ecosystems

Common name	Scientific name	Declaration status in QLD
Johnson grass	*Sorghum halapense*	Environmental (not declared)
Guinea grass	*Megathyrsus maximux var.maximus*	Environmental (not declared)
Para grass	*Urichloa mutica*	Environmental (not declared)
Easter cassia	*Senna pendula var glabrata*	Environmental (not declared)
Castor oil plant	*Ricinus communis*	Environmental (not declared)
Cats claw creeper	*Macfadyenaunguis-cati*	Class 3 WONS
Rubber vine	*Cryptostegia grandiflora*	Class 3 WONS
Singapore daisy	*Wedelia trilobata*	Class 3
Broad-leaved pepper tree	*Schinus terebinthifolius*	Class 3
Lantana	*Lantana camara*	Class 3 WONS

Pollution of riparian zones occurs in the form of littering and illegal dumping, especially in urban and peri-urban areas. Contaminated stormwater, escaped effluent and industrial discharges may be an issue in some areas, especially after large rainfall events or flooding. Mine discharges may pose an issue to riparian ecosystems in key mining localities as can the impacts of acid mine discharge, which occurs when acid sulfate soils are exposed to the atmosphere, forming acid run-off water. This is a major issue on the Dee River arising from the Mount Morgan mine's spoil heaps.

Agricultural chemicals such as herbicides arising from spray drift or run-off may impact riparian vegetation, as may industrial pollutants inadequately contained or accidentally released into watercourses.

Image of volunteers removing a shopping trolley and urban litter from Tigalee Creek in Kin Kora in Gladstone. (Photo courtesy Conservation Volunteers Australia)

> pollution of riparian zones occurs in the form of littering and illegal dumping

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for riparian ecosystems.

Restoration techniques for riparian ecosystems

Monitoring biodiversity	A. Photographic monitoring
	B. Ecological monitoring
	C. Water quality monitoring
Weed control	A. Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
	B. Manual – pulling, grubbing
	E. Mechanical – Brushcutting, slashing, dozing, stick raking or blade ploughing
Erosion control	A. Battering of slope
	B. Seeds and plants
	C. Rock
	D. Coconut fibre logs or hay bales
	E. Fencing – silt, dune, exclusion
	F. Woody debris
	G. Geofabrics
Revegetation	A. Tubestock planting
	D. Deep-stem planting
	E. (Limited) Cuttings and transplants
Litter reduction	A. Urban litter and marine debris survey
	B. Biofiltration
C. Gross pollutant traps	D. Socks
	E. Drain stencils
	F. Cigarette butt bins
	G. Tangler bins
Pest animal control	B. Traps
	D. (Limited) Fumigation
Homes for native wildlife	A. Hollow logs
	B. Wildlife boxes
	C. Fish passage
	D. Fish hotels

> in rural locations clearing and thinning of riparian zones is commonplace

Urban ecosystems and parkland

This chapter describes common urban ecosystems and parkland features, typical threats and pressures, and provides guidance on recommended restoration activities suited to urban ecosystems and parklands.

Ecosystem description

Urban ecosystems and parklands are generally highly modified landscapes. They may vary enormously in structure and composition, from areas of near-remnant habitat, through constructed landscapes of introduced plants with ordered gardens and plantings, parks of open mown lawns and grassy areas and few trees, and encouragingly an increasing number of urban parklands include native species plantings to recreate natural habitat types. In many urban environments some areas of remnant bushland may be retained. Often though, they are small in patch size, discontinuous with other related habitats, lack connectivity and are subject to weed invasion, dumping and impacts of introduced animals, including domestic species.

Most urban parklands must be artificially maintained. Most are tended by local councils and require significant mowing, weeding, tree and shrub maintenance such as pruning and thinning, and many gardens are mulched and irrigated. Litter is also regularly removed.

Images of various urban parklands in Gladstone. Top left: Natural-style plantings of 'Saltwater Scrub', Spinnaker Park, Gladstone. Top right: Created wetland with walking tracks and cycleways, Spinnaker Park, Gladstone. Bottom left: Open space near amenities block, Spinnaker Park. The amenities are located under the artificial hill in the background. Bottom right: Public art and childrens playground, Tondoon Botanic Gardens, Gladstone.

Images of urban parklands. Left: Urban parkland with remnant native vegetation, native species plantings, playground, walking paths and mown space in front of a constructed pond. Right: A heavily used urban parkland with barbecue and playground, Reg Tanna Park, Gladstone.

Recommended plants

Table 23

Recommended plants for urban parklands.

Common name	Botanical name	Mature height	Strata
Tuckeroo	*Cupaniopsis anacardioides*	8–10 m	Small tree
Mat rush	*Lomandra longifolia*	1 m	Groundcover
Weeping bottlebrush	*Melaleuca viminalis*	5–8 m	Small tree
Burdekin plum	*Pleiogonium timorensis*	10–15 m	Tree
Tulipwood	*Harpullia pendula*	10–12 m	Tree
Native coffee bush	*Breynia oblongifolia*	3–5 m	Shrub
Creek lilly pilly	*Syzygium australe*	8–10 m	Small Tree
Black tea tree	*Melaleuca bracteata*	5–8 m	Shrub/Small Tree
Flax lily	*Dianella caerula*	0.6 m	Groundcover
Field lily	*Crinum pendulatum*	1m	Groundcover

> in many urban environments areas of remnant bushland may be retained

Typical threats and pressures to ecosystem

Urban parklands are often designed to be used by humans for recreation. Many feature walking tracks, cycle ways, fitness installations, playgrounds, picnic tables, barbecues and public amenities. Some have skate parks and others have public art spaces or stages. As designated public spaces, a certain standard of upkeep is required so human intervention in the ecosystem is high from both users and managers. Management interactions include mowing, weeding, pruning and maintaining garden beds. User impacts may include wilful damage of vegetation (vandalism), or creation of pathways from pedestrian, cycling and motorised transport. Areas of urban bushland may be used for illegal motorbike and four-wheel drive use. These activities can compact soil, destroy vegetation and open the ground to erosion. They also help spread weeds and encourage illegal dumping.

Crime Prevention through Environmental Design (CPTED — pronounced Sep-Ted) is a crime prevention strategy that outlines how physical environments can be designed to lessen the opportunity for crime. The CPTED guidelines consider design and use, identify which aspects of the physical environment affect the behaviour of people and then uses these factors to allow the most productive use of space while reducing crime. This might include changes to poor environmental design, such as street lighting and landscaping. CPTED concepts and are ideally incorporated at a development's design stage, but can also be applied to existing developments and areas where crime and safety are a concern. They may need to be factored into any urban project site, particularly when picking vegetation species that could conceal illegitimate activities or inhibit the effectiveness of lighting (CPTED, Queensland Police).

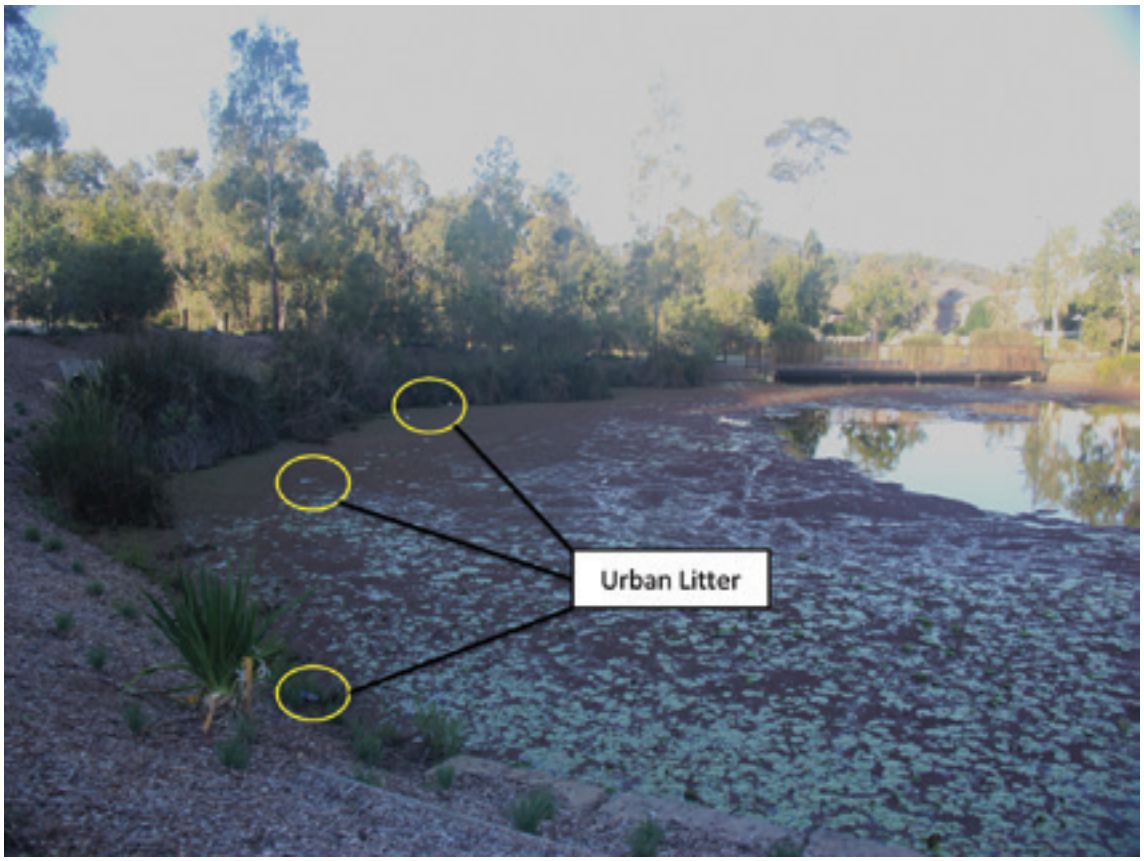


Image of urban parkland showing litter accumulating in a retention pond, Kirkwood Gladstone.

High public use may also disturb native wildlife and may lead to problems associated with wildlife and domestic species that adapt to urban landscapes. Dogs, cats, foxes, cane toads, exotic fish such as carp, mosquito fish and swordtails may all become an established problem in and around urban parklands. Certain bird species such as crows, magpies, rainbow lorikeets, seagulls, pigeons, ibis, noisy miners, Indian mynas and European sparrows may also thrive in these environments. These species are often aggressive and can dominate food supplies, nesting sites and out-compete smaller or less aggressive species.

In managed urban parklands, weed species are regularly controlled; however, many parks are actually planted with exotic species or species from outside their natural distribution. These species may have undesired impacts and could become problematic. For example, cadaghi *Corymbia torreliana*, a gum tree native to North Queensland, is widely planted as a street tree and in parks and gardens. In Central and Southern Queensland, this species is invading bushland and becoming an environmental weed. In less intensely managed urban areas, illicit dumping of garden waste into bushland or riparian areas may lead to invasion by escaped garden plants.

Ten common weed species

Table 24

Ten common weed species of urban parklands.

Common name	Scientific name	Declaration status in QLD
Khaki burr	*Alternanthera pungens*	Not declared
Siratro	*Macroptilium atropurpureum*	Not declared
Cobblers pegs	*Bidens pilosa*	Not declared
Nutgrass	*Cyperus rotundus*	Not declared
Red natal grass	*Melinis repens*	Not declared
Guinea grass	*Megathyrus maximus var maximus*	Not declared
Mother of millions	*Bryophyllum spp*	Class 3
Singapore daisy	*Wedelia trilobata*	Class 3
Broad-leaved pepper tree	*Schinus terebinthifolius*	Class 3
Lantana	*Lantana camara*	Class 3 WONS

Urban parkland with manicured lawns, landscaped gardens and designated drainages may not impede surface water flow as much as a natural system would. This can increase run-off, which then reduces infiltration into the soil and causes pulsed flows in waterways. Likewise, the increased run-off rate is likely to carry a larger sediment load and have more erosive capacity than a slower, more natural flow.

Increased human activities in an area may result in greater amounts of littering. Areas of urban bushland often become the sites for illegal dumping. Dumping garden waste often leads to exotic plant species being introduced, which may then become established weeds. Management activities may cause noise and dust pollution and further disturb native wildlife. It is also questionable whether the capacity of an artificial ecosystem maintained in a 'static' state by human intervention is sustainable and whether its capacity to sequester carbon dioxide would be as efficient as a natural system.

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for Eucalypt forest/woodland.

Restoration techniques for eucalypt forest/woodland

Monitoring biodiversity	A. Photographic monitoring
	B. Ecological monitoring
	C. Water quality monitoring
Weed control	A. Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
	B. Manual – pulling, grubbing
	E. Mechanical – Brushcutting, slashing, dozing/stick raking/blade ploughing
Erosion control	A. Battering of slope
	B. Seeds and plants
	C. Rock
	D. Coconut fibre logs and hay bales
	E. Fencing – silt, dune, exclusion
	F. Woody debris
	G. Geofabrics
Revegetation	A. Tubestock planting
	D. Deep-stem planting
	E. Cuttings and transplants
Litter reduction	A. Urban litter and marine debris survey
	B. Biofiltration
	C. Gross pollutant traps
	D. Socks
	E. Drain stencils
	F. Cigarette butt bins
	G. Tangler bins
Pest animal control	B. Traps
	D. (Limited) Fumigation
Homes for native wildlife	A. Hollow logs
	B. Wildlife boxes
	C. Fish hotels

Floodplain

This chapter describes common floodplain ecosystem features, typical threats and pressures and provides guidance on recommended restoration activities suited to floodplain ecosystems.

Ecosystem description

Floodplain ecosystems in the Fitzroy Basin are generally highly modified landscapes, especially in the lower Fitzroy floodplain as this was the area first settled and used for grazing. Past land management involved clearing, thinning and regular burning to encourage grass growth and to prevent native regrowth. Establishing improved pastures and creating ponded pastures has further altered much of this ecosystem type.

Floodplains do not generally retain water after flooding but may retain a mosaic of small, low-lying areas that retain water and are important local wetlands. These areas may be too small to appear on the Queensland Regional Ecosystems mapping data; however, they may be important reservoirs for species that will spread over the floodplains during floods, allowing genetic mixing and recolonisation of other wetland systems in the broader landscape. Floodplain ecosystems are closely allied with wetlands and riparian ecosystems and, in more saline areas, often merge into marine plains.

Common floodplain vegetation consists of a riparian (stream bank vegetation) zone and then either woodland, forest or grassland beyond this belt. As previously mentioned, much of this vegetation has been largely altered by human impacts. Much of the forests and woodlands have been thinned or cleared and only in a limited number of sites do large, old-growth trees still survive, providing tree hollows and animal refuge. Due to frequent fires and grazing pressure, there appears to be minimal recruitment.

Images of remnant large eucalypts on cleared grazing country on the Fitzroy River floodplain.

> floodplain ecosystems in the Fitzroy Basin are generally highly modified landscapes

Recommended plant species

Table 14.

Recommended plant species for floodplain ecosystems

Common name	Botanical name	Mature height	Strata
Queensland blue gum	*Eucalyptus tereticornis*	40 m	Tree
River red gum	*Eucalyptus camaldulensis*	20–25 m	Tree
Poplar gum	*Eucalyptus platyphylla*	20 m	Tree
Coolabah	*Eucalyptus coolabah*	15–18 m	Tree
Swamp mahogany	*Lophostemon suaveolens*	12–15 m	Small to medium tree
Black tea tree	*Melaleuca bracteata*	5–8 m	Shrub or small tree
Paperbark tea tree	*Melaleuca fluviatilis*	30 m	Tree
Weeping tea tree	*Melaleuca leucodendra*	25–30 m	Tree

Typical threats and pressures

Human impacts have been a major source of pressure on floodplain ecosystems. This has naturally arisen as early population centres were based on the rivers because they provided a means of transport, a ready supply of water, the soils tended to be more fertile, the land was generally level and the river offered opportunities for fishing, boating and relaxation.

Early settlement opened up the landscape and often clearing more land entitled a settler to make a larger claim. This created early impetus to clear scrub and bush to make way for grazing and cropping lands. Trees shaded out grass so trees were cleared and canopies thinned to encourage grass growth, helping to fatten sheep and cattle. Areas adjacent to rivers were also suitable for irrigation and the richer alluvial soils allowed for crop establishment. Increased development required construction of dams, weirs and levee banks to provide water and to help mitigate floods. This altered the natural hydrological cycle on which the floodplain ecosystem functioned. Too frequent burning to clear regrowth, control weeds, reduce bushfire risk and stimulate grass growth further damaged remnant vegetation. Introduced pasture species out-competed native grasses, over-grazing led to erosion and the clearing of large timber led to rising salinity issues in many areas. Introduced pasture grasses and woody weeds have contributed to hotter fires, which scorch and kill native regrowth and allow fires to penetrate deeper into riparian zones and compromising their structure. Cattle also contribute breaking down bank-side vegetation integrity, allowing weed encroachment.

Creating ponded pastures on low-lying areas of floodplains subject to seasonal inundation has altered natural water flows and salinity levels. It has also introduced grazing pressure into areas not traditionally heavily grazed. Embankments such as bunds and levees trap run-off water, creating artificial wetlands, which are often seeded with introduced pasture grasses that tolerate being inundated for extended periods. These species are often vigorous, resistant to grazing pressure and soon dominate native species. Hymenachne was introduced in the 1980s as a ponded pasture species and is now a Weed of National Significance. Bunds and levees also impede fish migration and may alter the species composition of waterways and wetlands.

Image of a ponded pasture on cleared grazing country on the Fitzroy River floodplain.

A number of Weeds of National Significance are associated with floodplain ecosystems. This possibly arises as a result of economics rather than a weed's invasiveness because the costs associated with lost productivity, control and management in prime grazing and cropping lands are seen to outweigh impacts in more natural ecosystems.

Many of the weeds associated with floodplains have been introduced as pasture or forage species and have been spread during floods or via stock movements. Many have also been introduced as contaminants of pasture seed or grain crops. A number of 'prickle bushes' (Acacia and Mimosa spp.) have become established across the region as has leucaena, parthenium, various prickly pear (Opuntia spp.) and both lantana and rubber vine. A plethora of introduced grasses also abound. These species have the capacity to increase fuel loads, generate hotter fires, smother native vegetation, block access and form dense monocultures. They also reduce biodiversity, upsetting the ecosystem's natural function.

Ten common weed species

Table 15

Ten common weed species of floodplain ecosystems

Common name	Scientific name	Declaration status in QLD
Hymenachne	*Hymenachne amplexicaulis*	Class 2 WONS
Guinea grass	*Megathyrsus maximus var.maximus*	Environmental (not declared)
Para grass	*Urichloa mutica*	Environmental (not declared)
Aleman grass	*Echinochloa polystachya*	Environmental (not declared)
Johnson grass	*Sorghum halapense*	Environmental (not declared)
Leucaena	*Leucaena leucocephala*	Environmental (not declared)
Rubber vine	*Cryptostegia grandiflora*	Class 3 WONS
Parkinsonia	*Parkinsonia aculeata*	Class 3 WONS
Parthenium	*Parthenium hysterophorous*	Class 3 WONS
Lantana	*Lantana camara*	Class 3 WONS

As many floodplains have a long history of urban settlement in Australia, it should not come as a surprise that urban waste dumping is a common form of pollution, especially adjacent to urban centres. Likewise, stormwater run-off contaminants such as oils and grease may also be an issue near larger urban centres. Industrial and commercial sites built on floodplains can contribute significant contaminants during extreme flood events. In many cases, industry is, however, in areas with a lower flood risk.

Other forms of pollution, such as nutrient enrichment from fertiliser run-off, can have detrimental effects on wetlands within a floodplain. Farm chemicals may be a source of pollutants, especially from old cattle dipping sites, or from run-off of herbicides and pesticides from crop lands. Special mention should be made of salinity as this is a major issue in large tracts of Australia. Clearing large trees allows the underground water table to rise close to the surface, carrying dissolved salts with it. Evaporation of water near the surface concentrates these salts, causing an increase in soil salinity. Using artificial fertilisers can exacerbate the problem and, in some areas, soil and groundwater is has become too salty for pasture or cropland. Rising sea levels associated with climate change may also add to salinity issues as saltwater incursions may penetrate further inland.

Recommended restoration activities

This section is from Appendix A: Ecosystem and Recommended Restoration Method Matrix; a guide to assist in selecting an appropriate restoration technique for Eucalypt forest/woodland.

Restoration techniques for eucalypt forest/woodland

Monitoring biodiversity	A. Photographic monitoring
	B. Ecological monitoring
	C. Water quality monitoring
Weed control	A. Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
	B. Manual – pulling, grubbing
	C. Biocontrol – grazing, bugs and fungi, groundcover competition
	D. Fire/thermal
	E. Mechanical – Brushcutting, slashing, dozing/stick raking/blade ploughing
Erosion control	A. Battering of slope
	B. Seeds and plants
	C. Rock
	D. Coconut fibre logs and hay bales
	E. Fencing – silt, dune, exclusion
	F. Woody debris
	G. Geofabrics
Revegetation	A. Tubestock planting
	C. Natural regeneration
	D. Deep-stem planting
Litter reduction	A. Urban litter and marine debris survey
	B. Biofiltration
	C. Gross pollutant traps
	D. Socks
Pest animal control	A. Nest protection – turtles
	B. Traps
	C. Baiting
	D. Fumigation
	E. Electrofishing
Homes for native wildlife	A. Hollow logs
	B. Wildlife boxes
	C. Fish passage
	D. Fish hotels

Appendices

Appendix A: Ecosystem and Recommended Restoration Method Matrix

It is vital to note that no one technique will suit all conditions on any particular project site. As such, this matrix is presented as a guide help select an appropriate technique. The chosen methodology must consider the conditions of the actual site, the species present, the weeds or pests and the scale of impact, the topography, terrain, geology and hydrology of a site. It is always advisable to seek local expert advice wherever possible. Searches of Wildlife Online, local government databases and regular observation of the species present at a site can all help guide which restoration methods are best suited. Remember the environment changes constantly, so regular observations and site monitoring can guide the process of restoration and the choice of methods to use. The severity of an impact and the prioritisation of works will also affect the most suitable method to use. Where possible, natural processes that minimise further disturbance to the site should be adopted.

Ecosystem	**Restoration techniques**						
	Monitoring biodiversity (A - C)	Weed control (A - E)	Erosion control (A - G)	Revegetation (A - E)	Litter Reduction (A - G)	Pest animal (A-E)	Homes for native wildlife (A - C)
Coastal foredune and beach	A B	B C Limited A	B D E F G	B C D E	A G H	A B C D	A B
Coastal beach scrub and headland	A B	B C Limited A	B C D E F G	A B C D E	A D	B C D	A B
Marine plain	A B	B	A B C D E F G	C E	A B C D	B C D	A C D
Wetland	A B C	B C Limited A	A B C D E F G	A C D	A B C D	A B C D E	A B C D
Semi-evergreen vine thicket (dry rainforest)	A B	B C Limited A E	B C D E F G	A B C E	A D	B C D	A B
Open eucalypt forest	A B	A C D E	A B C D E F G	A B C	A D	B C D	A B
Riparian	A B C	B C Limited A D E	A B C D E F G	B C D	A B C D	A B C D E	A B C D
Urban parkland	A B C	A B E	A B C D E F G	A D E	A B C D E F G	B Limited D	A B C D
Floodplain	A B C	A B C D E	A B C D E F G	A C D	A B C D	A B C D E	A B C D

Legend - Ecosystem and Recommended Restoration Method Matrix

Monitoring biodiversity
- A. Photographic monitoring
- B. Ecological monitoring
- C. Water quality monitoring

Weed control
- A. Chemicals – cut stump, basal bark, spraying, splatter gun, pellets
- B. Manual – pulling, grubbing
- C. Biocontrol – grazing, bugs and fungi, groundcover competition
- D. Fire/thermal
- E. Mechanical – brushcutting, slashing, dozing/stick raking/blade ploughing.

Erosion control
- A. Battering of slope
- B. Seeds and plants
- C. Rock
- D. Coconut fibre logs or hay bales
- E. Fencing – silt, dune, exclusion
- F. Woody debris
- G. Geofabrics

Revegetation
- A. Tubestock planting
- B. Direct Seeding - hydromulching, seed bombing
- C. Natural regeneration
- D. Deep-stem planting
- E. Cuttings and transplants

Litter reduction
- A. Urban litter and marine debris survey
- B. Biofiltration
- C. Gross pollutant traps
- D. Socks
- E. Drain stencils
- F. Cigarette butt bins
- G. Tangler bins

Pest animal
- A. Nest protection –turtles
- B. Traps
- C. Baiting
- D. Fumigation
- E. Electrofishing

Homes for native wildlife
- A. Hollow logs
- B. Wildlife boxes
- C. Fish passage
- D. Fish hote

Appendix B: Stakeholder analysis

For use in project scoping and planning stages to identify how the project will impact stakeholders.

Key stakeholders	**Nature of impact on stakeholder – consequences for that stakeholder/group**			**Stakeholder's importance**			**Engaging with the stakeholder**
Individual or group who may be affected by the project.	How will the stakeholder influence the project? What is their interest in the project?	What project stage will the stakeholder influence? When is their participation suitable?	How can the project take advantage of the stakeholder (such as stakeholder's skills)? What can the project do for the stakeholder (that is, what are the outcomes for the stakeholder)?	Level of Impact • High • Medium • Low	Level of influence 1. Important 2. Influential 3. Mandatory 4. Beneficiary 5. Impactee	Level of involvement A. Inform B. Consult C. Involve (seek participation) D. Collaborate (partner)	What is the strategy for engaging with this stakeholder? What consequences may arise if they are not engaged?

Appendix C: Tangaroa Blue Marine Debris data sheet

Data Collection Sheet

Tangaroa Blue Foundation
PO Box 1176 Margaret River WA 6285 www.tangaroablue.org

Name of Cleanup Location (Beach)			
Cleanup Locality			**Locality Postcode**
Nearest Town		**Nearest Road or Landmark**	
Date	**Start time**	**Finish time**	**Number of People**
Contact Name		**Phone or email**	
Organisation/School (if applicable)			
Total Filled Bags	**Total Weight Kg**		**Length of Beach Cleaned (m)**
Average Width of Beach (m)		**Type of Adjoining land**	

Please enter items not listed below in the additional items section or on an attached sheet.
Country of origin and barcode information from intact labels can be entered in the tally and note section against the particular item or on a separate sheet. A secondary data sheet is also available to record this and other information.

	Plastic Items	Total	Tally and Note
Consumer Items	Cigarette butts & filters		
	Cigarette lighters		
	Pens, markers & other plastic stationary		
	Straws, confection sticks, cups, plates & cutlery		
	Toothbrushes, brushes & combs, hair ties etc		
	Toys, party poppers, ribbons, clips & similar		
Packaging Items	Bleach & cleaner bottles		
	Lids & tops, pump spray, flow restrictor & similar		
	Personal care & pharmaceutical packaging		
	Plastic bags supermarket, garbage, dog poo, ice		
	Plastic containers non food (oil, sealant, chemical)		
	Plastic drink bottles (water, juice, milk, soft drink)		
	Plastic packaging food (wrap, packets, containers)		
	Plastic wrap non food (bubble wrap etc)		
	Strapping band scraps		
	Strapping band whole (record as single item)		
Fishing Items	Bait & tackle bags & packaging		
	Bait containers & lids, bait savers		
	Commercial fishing remnants (float, pot, crate bits)		
	Cylume glow sticks		
	Fishing line in metres (recreational)		
	Recreational fishing items (lures, floats, rods, reels)		
	Rope & net scraps less than 1 metre		
	Rope (estimated length in metres)		
Remnants	Plastic bits & pieces hard & solid		
	Plastic film remnants (bits of plastic bag, wrap etc)		
	Remnants burnt plastic		
	Foamed Plastic (Polystyrene) Items	**Total**	**Tally and Note**
	Foam buoys		
	Foam cups, food packs & trays		
	Foam insulation & packaging (whole and remnants)		
	Other Materials	**Total**	**Tally and Note**
	Oil globules & tar-balls		
	Sanitary (tissues, nappies, Condoms, cotton buds)		
	Shoes leather & fabric		

Data Collection Sheet

Tangaroa Blue Foundation
PO Box 1176 Margaret River WA 6285 www.tangaroablue.org

AUSTRALIAN MARINE DEBRIS INITIATIVE

Glass & Ceramic Items	Total	Tally and Note
Fluorescent light tubes and bulbs		
Glass beer stubbies & pre-mixed alcohol bottles		
Glass jars & sauce bottles		
Glass or ceramic broken		
Glass wine, spirit and similar bottles		
Cloth Items	**Total**	**Tally and Note**
Binding, thread, string & cord natural		
Cloth, clothing, hats & towels		
Metal Items	**Total**	**Tally and Note**
Aerosol cans		
Aluminium cans		
Foil wrappers, packets, bladders & alfoil		
Metal bottle caps, lids & pull tabs		
Metal fishing items (sinkers, lures, hooks, traps, pots)		
Tins under 4 litres (food, drink tins and similar)		
Paper & Cardboard Items	**Total**	**Tally and Note**
Newspaper, magazines & brochures		
Paper & cardboard packaging		
Tetra packs & drink cartons		
Rubber Items	**Total**	**Tally and Note**
Rubber balloons, balls & toys, elastic straps & bands		
Rubber footwear & thongs		
Rubber remnants		
Wood Items	**Total**	**Tally and Note**
Brooms, brushes & paint brushes		
Processed timber, pallets & other wood		
Wooden confection sticks, pencils, matches etc		
Additional Items	**Total**	**Notes**
Additional Information	(Circle)	**Comments**
Did you observe any **plastic resin pellets**?	**Y N**	
Did you observe any dead/injured **animals or birds**?	**Y N**	
Did you observe any highly unusual **beach conditions**?	**Y N**	
Other comments and feedback