CHAPTER 9

WEEDS

KERRY BODMIN

CONTENTS


WEEDS

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KERRY BODMIN

Weed pressure on environmentally sensitive places such as wetlands is increasing, with approximately 20 new plants per year becoming naturalised in New Zealand ecosystems. Weeds are one of the most visually obvious signs of human-induced impacts on a wetland. A weed, also commonly called a pest plant, can simply be defined as a plant growing where it is not wanted. In restoration projects weeds are usually introduced or exotic plants that are not native to New Zealand. Weeds pose a threat to wetlands as they can modify the structure or function of the wetland (including nutrient and hydrology regimes), out-compete native plants, change the vegetation, alter the habitat and resources available for native insects, birds and fish, and affect access or restoration activities.

This chapter provides a step-by-step guide on how to achieve effective weed control through clear project aims or restoration goals, identification of weed issues, selection and application of appropriate treatment methods, timing of work, follow up, and monitoring. Although a range of priority weeds has been included, the list is not exhaustive. Comprehensive weed lists to help identify what weeds you have in and around your wetland can be accessed from the useful websites listed at the end of the chapter.

The two case studies in this chapter demonstrate approaches to controlling crack and grey willow, as both are a serious threat to freshwater wetlands. The first case study is situated in the Waikato and showcases a largely community-led restoration project around two shallow lakes; the second is a large, freshwater swamp in west Auckland surrounded by a mosaic of land uses. Both provide valuable lessons on how to control major weed infestations.

Previous page: Crack willow invading margins of Lake Taupo, Waikato.
Photo: Monica Peters, NZ Landcare Trust

Keeping remnant wetlands intact by minimising disturbance helps buffer them from weed invasion. The extensive raupo sward is in winter dieback. Matakana Island, Bay of Plenty. Photo: Monica Peters, NZ Landcare Trust

Mechanical vegetation clearance, drainage and ongoing disturbance, e.g., fire, have left wetland remnants highly vulnerable to weed invasion. Waihi, Bay of Plenty.
Photo: Monica Peters, NZ Landcare Trust

1 Restoring your wetland

Any restoration programme will need to address weeds and outline actions for their control. Effective weed reduction or removal will not only aid the survival of native plant species but also provide wider benefits to the wetland including increased habitat for native fauna, conservation of rare species, and retention of ecosystem processes.

1.1 Developing a Wetland Restoration Plan

A Wetland Restoration Plan is extremely useful for clarifying goals and objectives as well as on ground activities. Either use an existing template (links are at the end of the chapter) or create your own based on the format provided in Chapter 2 – Restoration planning.

1.1.1 Mapping

A bird's-eye view sketch map of the wetland is a useful tool for summarising knowledge about the natural and man-made character of the site as well as assisting with planning and management. The map can be hand drawn using a range of resources such as aerial photographs, topographic maps and Google Earth combined with your own knowledge. Once the features listed below have been included, management zones can be defined. Locations of permanent plots for monitoring and isolated weeds (including GPS co-ordinates if available) can also be included to aid restoration site management.

General features to include:

- Vegetation types
- Water sources and outflows, hydrological modifications, water levels
- Soil type(s)
- Natural, man-made and cultural features

For more detail on what to include, see Chapter 2 – Restoration planning

1.2 Determining wetland type

Find out what type your wetland is/was, e.g., swamp, fen, bog, marsh and/or shallow water, because different wetland types have specific nutrient and hydrological regimes that favour distinctive plant communities. Note that larger wetlands may be made up of more than one wetland type. See Chapter 3 – Wetland types for further information.

1.3 Using a reference wetland

You can get some clues on wetland type from what native plant species remain in your wetland, from the soil type (e.g., presence of peat), by visiting similar wetlands in the vicinity, or by researching historical records. A little investigation on the relevant wetland type in your region should also reveal information on the typical or main vegetation communities (including current and potential weeds), habitats, plant and wildlife species, and rare species, which can help focus your restoration project. Historical photographs and/or local knowledge may also reveal useful information about weeds. These sources could help determine whether weeds are spreading and if so, how quickly, or whether weeds have remained in discrete areas. Further information on finding and using reference wetlands can be found in Chapter 4 – Site interpretation 1. More in-depth studies to learn about the history of the wetland can be found in Chapter 5 – Site interpretation 2.

Aquatic habitats are under threat from introduced plants such as egeria (*Egeria densa*), which also negatively affect populations of native fauna such as koura. Photo: Rohan Wells, NIWA

1.4 Setting realistic goals and objectives

Goals need to be realistic and in line with the resources (time and money) that are available. An example of a goal may be to carry out regular surveillance to ensure no new weeds become established, and to rapidly eliminate any new weeds discovered. The goal(s) of the restoration project will determine if an introduced plant is considered a weed. For example, oak and feijoa trees are important duck food sources and willows can provide trout habitat, but none of these plants would be desirable in a native ecological swamp restoration project.

Objectives linked to goals should be clear and concise, and if possible measurable within a set time frame such as:

- Reduce the grey willow area from 70% to 20% in three years
- Determine high priority weeds and control in the most intact part of the wetland first
- Reduce invasion by marginal weeds such as gorse, broom and pampas by restoring water inflows and preventing wetland margins from drying out.

Rewetting Hannah's Bay wetland (Rotorua) has resulted in a change of species from dryland to wetland, aided by weed control and plantings of natives. Photo: Monica Peters, NZ Landcare Trust

Mechanical disturbance coupled with changing the hydrology of the wetland have enabled weeds including grey willow, gorse and royal fern to establish. Kopuatai peat dome, Waikato.
Photo: David Stephens for DOC

1.4.1 Keeping it legal

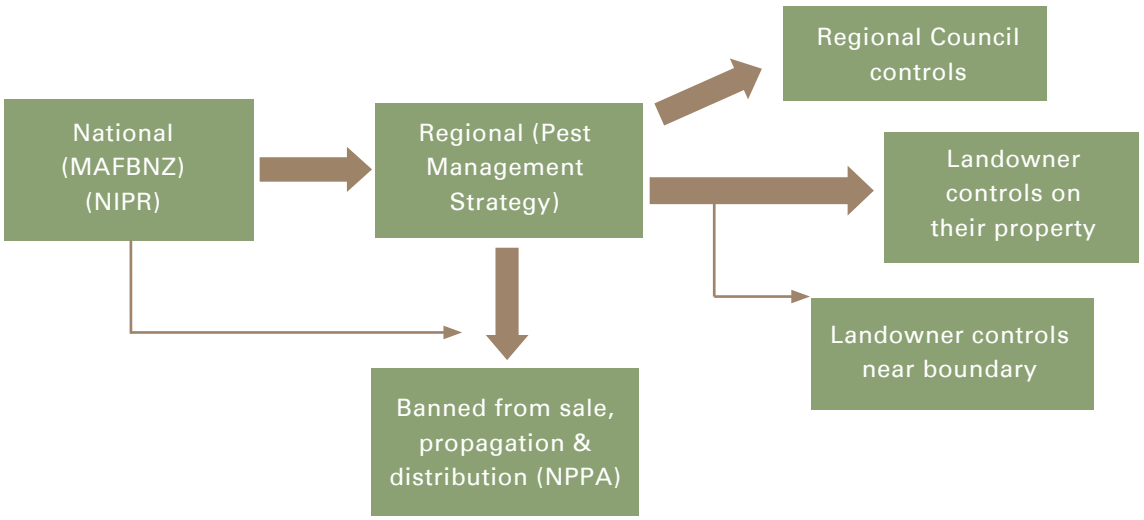
There are a limited number of herbicides registered for use in or near waterways. It is important to check the herbicide label for application instructions, and be aware that in some cases resource consent is required from your local or regional council.

Once you have determined your wetland weeds, check them against national and regional biosecurity weed lists to determine their legal status. If the weed is new to New Zealand or has been identified as a plant of national priority then notify the Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) as it falls under their jurisdiction (see the end of the chapter for links to websites).

Regional Councils each have their own Regional Pest Management Strategy (RPMS). The purpose of the strategy is to set out the strategic and statutory framework for the effective management of pest plants/weeds and pest animals. Under the RPMS, selected pest species are either the responsibility of the regional council or the landowner.

The majority of weeds listed, however, are simply banned from sale, propagation and distribution (Figure 1). RPMS for different regions can be found on Regional Council websites.

Before conducting any weed control also check council rules, plans and regulations at both a regional and district or city council level. Regional council plans, such as the Air, Land & Water Plan, set out restrictions on the use of fires, discharges to water, or earth works. District or city councils have district plans that may include restrictions on vegetation clearance, work within riparian margins or landscape protection.



NIPR = National Interest Pest Response
NPPA = National Plant Pest Accord

Figure 1. The national and regional weed management strategy designating responsibility for weed control and distribution.

Of the 24 700 introduced plants currently in New Zealand, 10% will establish in the wild, and 10% of these will become serious weeds. Arum lilies at Whatipu, Auckland.

Photo: Monica Peters, NZ Landcare Trust

1.5 How and why do weeds invade wetlands?

The number of introduced species in New Zealand already significantly outnumbers native species. Weeds can become established in a wetland through a variety of ways. Lower wetland water tables through drainage enable plants tolerant of drier conditions to become established – typically these include gorse (*Ulex europaeus*), blackberry (*Rubus fruticosus*), and pampas (*Cortaderia selloana* and *C. jubata*). Vegetation clearance in landscapes that are already heavily modified and have well-established weed populations enables rapid weed colonisation aided, for example, by wind, birds or people. Weeds can be spread unintentionally (e.g., on clothing, footwear or machinery) as well as intentionally. An example is the introduction of weedy aquatic species in the belief that beneficial habitat is being provided for coarse fish species.

However, even relatively undisturbed wetlands are vulnerable to invasion. Some of the weeds outlined in the next section – the "environmental weeds" – are extremely aggressive invaders capable of exploiting native plant habitat, particularly if it is nutrient enriched. Good examples are some of the aquatic weeds that, due to their dense growth habit and sheer size, are able to successfully outcompete smaller growing natives. Grey willow (*Salix cinerea*) is a species able to colonise undisturbed sedgelands by producing prolific quantities of seeds. Possibly the only exception for suceptibility to grey willow invasion because their naturally low nutrient status and acidic conditions are not as favourable for the higher nutrient-demanding, introduced species currently found in wetlands throughout New Zealand. However, the case study in Chapter 7 – Hydrology, demonstrates that bogs too become vulnerable to weed invasion once the water table has been lowered or nutrient enriched.

2 Identifying weed issues and priorities

Identifying what wetland weeds you have can be a daunting task; however, there are several weed identification guides available on websites listed at the end of this chapter. One easy, on-line key for weeds listed in the National Pest Plant Accord (NPPA) is the LucidKey, which starts with the easiest characteristics (like flower colour, for example) and works through the other characteristics.

WEED IDENTIFICATION – WHO CAN HELP?

It is important to identify your wetland plants correctly so that natives are not inadvertently killed as weeds, and weeds aren't accidentally fostered as natives. A number of web-based identification guides are available – see the useful websites section at the end of the chapter. Other resources to help you with plant identification are herbarium collections, your local botanical society, Regional Council biosecurity staff, and wetland experts from, e.g., NIWA, Landcare Research and universities.

Introduced pampas (*Cortaderia* ssp.) flowering heads have a strongly upright habit. The dead plants in the foreground show the typical mounding of rhizomes and curled remnants of leaf bases.
Photo: Monica Peters, NZ Landcare Trust

Dead leaf bases of introduced pampas are tightly curled. Photo: Monica Peters, NZ Landcare Trust

Weeds can be ranked as high, medium or low priority according to the threat they pose to the ecological integrity of the site. Factors to consider are the life form of the weed, where it is growing, how fast it can spread, and what impact it can have. The most damaging weeds are known as environmental weeds, which are capable of:

- changing the structure or function of a wetland, e.g., sedgeland (low growing) invaded by grey willow (tree)
- spreading rapidly, e.g., alligator weed
- outcompeting native plants, e.g., royal fern

Leaf bases of native *Cortaderia* ssp. have a waxy bloom.
Photo: Monica Peters, NZ Landcare Trust

Friend or foe? There are several features that distinguish native *Cortaderia* species (toetoe, *Cortaderia fulvida* shown) from their introduced cousins. Native flowering heads are mostly lax, and leaf bases have a distinctive waxy bloom. Photo: Rohan Wells, NIWA (with permission from Mighty River Power)

By contrast, low priority weeds integrate into the wetland with little or no perceived impacts. Pasture grasses and ragwort, for example, may not threaten the long-term health of the wetland but may require control to ensure they are kept lower than any native vegetation regenerating or planted.

Weeds can be both low and high priority, depending on where they grow and where they have highest impact. For example, Mercer grass (*Paspalum distichum*) is a low priority in paddock margins but a high priority when floating mats reduce the area of open water. Oval sedge (*Carex ovalis*) is a minor weed of tall vegetation but is a major turf weed. Pampas grass inhabits drier areas, making it a low priority weed on wetland margins but a high priority weed on ephemeral wetlands.

2.1 High priority weeds

Examples of high priority weeds that can transform a wetland are listed below according to their growth form (Table 1); and Table 2 illustrates some of the worst weeds to look out for in each wetland type. The Department of Conservation (DOC) has produced a list of 300 environmental weeds found on conservation estate land. A range of weed species are banned from sale, propagation and distribution throughout New Zealand under the National Pest Plant Accord. Regional councils and unitary authorities expand this list to include weeds that are of particular concern for their areas (see the Useful websites section at the end of the chapter).

Floating mat of Mercer grass (*Paspalum distichum*) in foreground encroaching on native wetland plants. Lake Mangahia, Waikato.
Photo: Kerry Bodmin NIWA (with permission from Environment Waikato)

Table 1. High priority weeds: Wetland transformers by growth form

Growth form	Common name*	Latin name	Wetland type
Trees	crack willow	*Salix fragilis*	Swamp, riparian zone
	grey willow	*Salix cinerea*	Swamp, fen
	alder	*Alnus glutinosa*	Swamp, riparian zone
Subcanopy/ shrubs	Chinese privet	*Ligustrum sinense*	Swamp, fen
	Chilean rhubarb	*Gunnera tinctoria*	Seepages
	gorse	*Ulex europaeus*	Bog
Vines and ferns	Japanese honeysuckle	*Lonicera japonica*	Marginal zone, swamp forest
	old man's beard	*Clematis vitalba*	Marginal zone, swamp forest
	royal fern	*Osmunda regalis*	Fen, bog
Herbaceous	purple loosestrife	*Lythrum salicaria*	Swamp, fen
	yellow flag iris	*Iris pseudacorus*	Swamp, salt marsh, fen, riparian margins
	arum lily	*Zantedescia aethiopica, Zantedescia aethiopica 'green goddess'*	Swamp
Rushes	sharp rush	*Juncus acutus*	Dune ephemeral wetland
	heath rush	*Juncus squarrosus*	Bog, ephemeral wetland turfs
	Californian club rush	*Schoenoplectus californicus*	Estuarine margins
	bulbous rush	*Juncus bulbosus*	Turf communities, seepage
Sedges	oval sedge	*Carex ovalis*	Fen, ephemeral wetland turfs
	Carex scoparia	*Carex scoparia*	Swamp, fen
Grasses	reed canary grass	*Phalaris arundinacea*	Swamp
	reed sweet grass	*Glyceria maxima*	Swamp
	Phragmites	*Phragmites australis*	Swamp, fen
	Manchurian wild rice	*Zizania latifolia*	Swamp, riparian zone
	pampas	*Cortaderia jubata* *C. selloana*	Ephemeral wetlands, marginal zone, pakihi, gumland
	Spartina	*Spartina alterniflora, Spartina anglica, Spartina x townsendii*	Saltmarsh, dune ephemeral wetland
Sprawling	alligator weed	*Alternanthera philoxeroides*	Swamp, marsh
	parrot's feather	*Myriophyllum aquaticum*	Swamp, marsh
Submerged	Lagarosiphon/ oxygen weed	*Lagarosiphon major, Elodea canadensis*	Shallow water
	hornwort	*Ceratophyllum demersum*	Shallow water
	Egeria	*Egeria densa*	Shallow water

* Note that common names can vary widely

Californian clubrush flowering heads.
Photo: Paul Champion, NIWA

Reed sweet grass forms dense mats on water and in damp areas. Photo: Paul Champion, NIWA

Long lived, arum lilies form dense patches. Photo: Monica Peters, NZ Landcare Trust

Gypsywort growing among raupo and smothering Carex spp.
Photo: Monica Peters, NZ Landcare Trust

Purple loosestrife produces abundant long-lived, highly viable seeds. Photo: Kerry Bodmin, NIWA

Grey willow poisoned and left to break down. Howarth Memorial Reserve, Waikato.
Photo: Monica Peters, NZ Landcare Trust

Table 2. Worst weeds by wetland type

Wetland type	Common name*	Latin name
Bog	royal fern	*Osmunda regalis*
	heath rush	*Juncus squarrosus*
	strawberry myrtle	*Ugni molinae*
	blueberry	*Vaccinium corymbosum*
	gorse	*Ulex europaeus*
Fen	royal fern	*Osmunda regalis*
	grey willow	*Salix cinerea*
	Phragmites	*Phragmites australis*
	oval sedge	*Carex ovalis*
	purple loosestrife	*Lythrum salicaria*
Swamp	grey willow	*Salix cinerea*
	crack willow	*Salix fragilis*
	alder	*Alnus glutinosa*
	gypsywort	*Lycopus europaeus*
	jointed rush	*Juncus articulatus*
	purple loosestrife	*Lythrum salicaria*
	reed canary grass	*Phalaris arundinacea*
	reed sweet grass	*Glyceria maxima*
	Phragmites	*Phragmites australis*
	Manchurian wild rice	*Zizania latifolia*
	alligator weed	*Alternanthera philoxeroides*
	yellow flag iris	*Iris pseudacorus*
	parrot's feather	*Myriophyllum aquaticum*
Marsh	alligator weed	*Alternanthera philoxeroides*
	parrot's feather	*Myriophyllum aquaticum*
	tall fescue	*Schedonorus phoenix*
	Mercer grass	*Paspalum distichum*

* Note that common names can vary widely

Wetland type	Common name*	Latin name
Seepage	rush	*Juncus acuminatus*
Ephemeral	blackberry	*Rubus fruticosus*
	gorse	*Ulex europaeus*
	pampas	*Cortaderia jubata, C. selloana*
	sharp rush	*Juncus acutus*
	bulbous rush	*Juncus bulbosus*
	oval sedge	*Carex ovalis*
Shallow water	parrot's feather	*Myriophyllum aquaticum*
	Mexican waterlily	*Nymphaea mexicana*
	Lagarosiphon	*Lagarosiphon major*
Pakihi and gumland	pampas	*Cortaderia jubata, C. selloana*
	prickly hakea	*Hakea sericea*
	downy hakea	*H. gibbosa*
	Spanish heath	*Erica lusitanica*
	gorse	*Ulex europaeus*

* Note that common names can vary widely

Royal fern displaying autumnal colours. Photo: Abby Davidson, NZ Landcare Trust

2.1.1 Understanding the weed issue

For each habitat type within your wetland you can determine what pest plants you have, where they're located, and what area they cover. If you have access to historical information, either photographs or local knowledge, you can determine if the weed population is invading and how fast it is spreading or if the spread has been relatively constant over time.

Often there will be more weeds than you can tackle at once. Weeds that you have the least of, but which could rapidly invade your wetland, should generally be prioritised above those weeds that are already abundant and have occupied much of their available wetland habitat. Also check the lists of environmental weeds in the useful websites section at the end of the chapter to see what weeds you don't have. Are these weeds nearby? If so, what's the likelihood of their spreading to your wetland?

Alligator weed, native to South America, is regarded as one of the world's worst weeds. Photo: Paul Champion, NIWA

Attractive flowers are one reason the Mexican waterlily was introduced. Photo: Rohan Wells, NIWA

The banana shaped tubers are a key diagnositic feature of the Mexican waterlily – useful when no flowers are present. Photo: Rohan Wells, NIWA

CASE STUDY

CONTROLLING GREY WILLOW AT LAKES KAITUNA AND KOMAKORAU

The lakes to the north of Hamilton City form part of a chain of more than 30 shallow peat lakes that extend along historical routes of the Waikato River. Over the course of a few decades, grey willow (*Salix cinerea*) invaded the margins of both Lake Kaituna (15 ha) and the adjacent Lake Komakorau (2.6 ha), considerably reducing the area of open water. Much to the concern of the landowners, the invasion of willow and other weeds combined with declining lake water impacted on native wildlife populations – few birds were to be seen. To remedy this, a lake care group was formed, and partnerships developed between the group, Environment Waikato and DOC.

The beginnings

Ground work to clear dense thickets of grey willow at Lake Kaituna started in 1999. A host of other weeds including royal fern (*Osmunda regalis*), blackberry (*Rubus fruticosus*), crack willow (*Salix fragilis*) and Japanese honeysuckle (*Lonicera japonica*) were also removed in the process. Both lakes were fenced to prevent stock access, and silt traps and vegetation filters were constructed on drains to prevent direct entry of nutrient and sediment laden water to the lakes.

Ground-based control

Beginning upwind to avoid reinfestation of cleared areas, grey willow was felled and stumps painted with 4 parts diesel and 1 part Roundup™. These works were carried out Dec–Jan to take advantage of low water levels. A digger then stacked the willow in piles working from the margins further into the wetland. Willow rots quickly and this method allowed native sedges and eventually other wetland species to reestablish quickly. After 3–5 years, the felled willow has almost entirely rotted away, with the area now largely colonized by native sedges.

Aerial control

Areas where the water was too deep were helicopter sprayed with 9L Roundup™, 500 ml Pulse penetrant and 1 L Delfoam anti-drift agent in 200 L water. Follow-up work is focused on controlling willow seedlings, blackberry, beggars tick (*Bidens frondosa*), and gypsywort (*Lycopus europaeus*), through a combination of handpulling/grubbing and spot spraying with Roundup™.

Funding

Complete removal of ~16 ha of willow from both lakes took 7 years at a total cost of around $60,000. This sum includes financial contributions from Environment Waikato, DOC (both lakes are Wildlife Management Reserves), the landowner farming around the lakes, and the local lake care group. Not included in this sum is the considerable unpaid time and resources the landowner and lake care group have contributed toward weed clearance, planting, pest control, and plant maintenance.

– Monica Peters, NZ Landcare Trust and Andrew Hayes, Lake Kaituna and Komakorau Care Group

REF: www.landcare.org.nz/files/file/841/Hayes%20Case%20Study%20Revised%20May%202012.pdf

Willows completely cleared from Lake Kaituna and regeneration well underway. The grayish stands of willow on the adjacent lake (Komakorau) have since been removed. Photo: Environment Waikato

Large-scale restoration takes large-scale approaches: a digger was necessary to remove the dense stands of grey willow.
Photo: Rodney Hayes

Lake Kaituna as seen from the farm. Photo: Monica Peters, NZ Landcare Trust

3 Weed treatment methods

What treatment methods you use will depend on the project aims or restoration goals you have set and the resources available. The aim of treating a particular section or pest plant within your wetland falls into one of three categories:

- **Containment** – to restrict further spread
- **Control** – to reduce the population or knock it back periodically
- **Eradication** – to eliminate the population

Eradication is generally the most expensive option, but may be appropriate when there are only a few plants or they occupy a limited area, there is a good treatment method, and the risk of reinvasion is low. You may select a combination of different aims for your wetland depending on the site and the weeds present. When selecting a treatment option consider the effectiveness of the treatment on your target weed and also in the type of wetland you have, the practicality of using that method, the cost and resources required, the environmental impacts, the risk of reinvasion by water, birds, wind and people, and the acceptability of the method to the community.

The most effective initial control method may differ from the ongoing control method.

Examples of weed treatment options include:

- **Manual** – hand weeding, digging, using animals to graze site
- **Mechanical** – chainsaw
- **Biological** – biocontrol such as willow sawfly
- **Chemical** – herbicide application
- **Physical** – fire, temporarily flooding
- **Combination of approaches** – drilling and injecting with herbicide; cutting, frilling and painting with herbicide
- **Do nothing** – no action taken

3.1 Disturbance

Try to keep disturbance at a site to a minimum as most weeds thrive on disturbance. It may be that a 'do nothing' approach is required when the collateral damage to non-target (desirable) plants will be too great or when control of a weed could lead to a worse weed invading. Restoration works carried out at Te Henga wetland (Auckland) provides a striking example of two very different

Willows were drilled and injected with herbicide. Large-scale disturbance through mechanical removal has allowed weed invasion. Photo: Paul Champion, NIWA

outcomes from willow control. The sites in the photographs below were directly adjacent to each other in Te Henga Wetland. Disturbance through removal of poisoned willows from the site exposed bare soil that allowed pampas grass to invade. By contrast, dead willows were left standing in the directly adjacent site where a predominantly native understorey has established.

There are added benefits to keeping willow as standing deadwood as they also provide moderate shade, shelter and habitat, e.g., bird roosting sites. Over time, dead willow wood density declines and the trees break down very easily. Small branches fall regularly, minimising damage to regenerating vegetation.

3.2 Hydrology

Water levels in modified wetlands are often significantly reduced, contracting the wetland and allowing more terrestrial plant pests such as blackberry, gorse and pampas to take hold. Restoring the amount of water in the wetland, and reinstating the natural seasonal fluctuations, can prevent many weeds from establishing and assist with control of terrestrial species. See Chapter 7 – Hydrology, for further information.

3.3 Nutrients

The addition of nutrients to a wetland system can alter the type of wetland and therefore facilitate the introduction of new weeds. If nutrient input to the wetland cannot be prevented, consider the planting of high nutrient stripping plants, such as raupo, at the inflows. See Chapter 8 – Nutrients, for further information.

HERBICIDES – WHICH ONE TO USE?

A wide range of herbicides are available for controlling weeds. Diquat® can be used in water for the control of some submerged species. Glyphosate® (or Roundup) is a broad spectrum herbicide with some formulations registered for use on or near waterways. Gallant® is specifically targeted to control grasses but should not be used where contamination of water can occur. Vigilant® gel is applied directly to target weeds such as gorse. People applying the herbicides should have "Growsafe" (www.growsafe.co.nz) certification for safe handling and chemical application.

Willows were drilled and injected with herbicide and left as standing deadwood. An understory of native species has successfully begun to regenerate. Photo: Paul Champion, NIWA

4 Preventing weeds

A regular surveillance regime provides early detection of new weeds and allows a rapid response. Control of recent invaders at an early stage is usually cheaper, more likely to be successful in eradication, and prevents the formation of a seed bank.

Several tools and practices can be used to minimise weed invasion. If control of a pest plant is problematic, removal of the seed head prevents further spread. Good weed hygiene practices, such as removing seeds from boots and clothing, prevent seed spread. Maintaining a good vegetation cover also prevents weeds establishing. At a larger scale you may consider a vegetation buffer around your wetland to reduce weed invasion. A buffer also has the added benefits of intercepting runoff, excluding stock, and providing different fauna habitat. A catchment management plan can be used as a tool for weed control beyond the wetland, particularly from immediate neighbours and those upstream of the wetland.

WEEDS: TOP TIPS FROM THE COMMUNITY

- Know your weeds from your natives, how the weed grows, spreads and thrives
- When targeting an area, tackle all the weeds in that area
- Don't bite off more than you can chew
- Plan and do follow-up weed control, about every 3 months
- Aim to eradicate priority weeds from the site
- Prevent weed spread from or to the site on shoes, clothing and equipment
- Reduce habitats that favour weeds through planting or minimising disturbance

Dead grey willow with royal fern (reddish colour) invading Whangamarino, a Ramsar wetland administered by the Department of Conservation. Waikato. Photo: Kerry Bodmin, NIWA

5 Timing of work

Selecting the appropriate time of year for treatment is one of the most critical steps for successful weed control. It is important to consider not only the optimal time to strike your target weed, but also when other non-target species are least susceptible, such as undertaking weed control after orchids have flowered and died back to a bulb below the ground. The optimal time for herbicide applications is generally when the plant is actively growing, but before it flowers or sets seed. Avoid control when plants are stressed, such as from too much or too little water. Most weed control usually occurs in spring or summer when plants are growing vigorously and in full leaf.

5.1 Follow up

Successful control or eradication of weeds requires skilful targeted application of treatment, appropriate timing, and rigorous follow up, follow up, follow up. The method selected for follow-up weed control may differ from initial control methods. For example, a large expanse of crack willow that is initially treated by aerial spray has follow-up control by ground-based spot spraying or drilling and injecting. Multiple treatments are often required with regular follow up.

Weeds that require light to survive will be less vigorous or die out once a canopy of desirable plants is established. These light-demanding weeds can provide some intermediate benefits, such as soil moisture retention, but need to be kept below planted natives to prevent the native plants from being out competed and smothered. Other pest plants, such as Chinese privet and royal fern, tolerate shade and will require ongoing maintenance. Timing of follow-up control work needs to be scheduled regularly, usually every 2–3 months, or more regularly in good growing conditions. Any follow-up work needs to take account of other activities on which it may impact, especially planting.

Controlling weed infestations in wetlands is without a doubt challenging! Good safety gear and a sound knowledge of chemical and tool handling are essential. Photo: Wildland Consultants Ltd.

Weed reinvasion remains a constant threat. Grey willow seedling, Hannah's Bay wetland, Rotorua. Photo: Monica Peters, NZ Landcare Trust

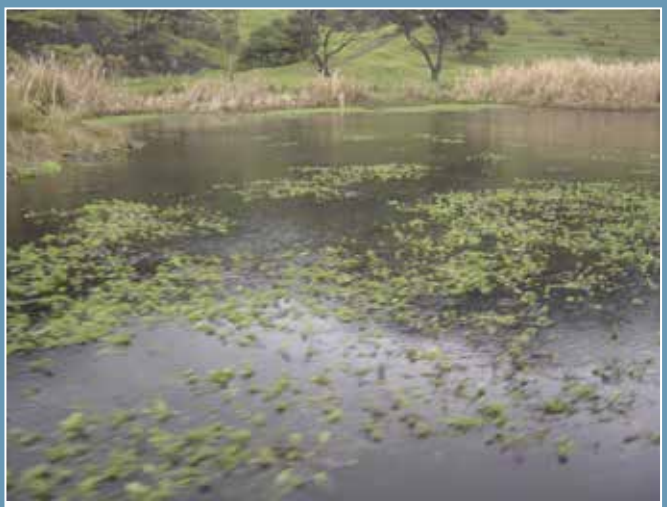
An island of willows that has been controlled.
Photo: Danielle Hancock, Waitakere City Council

The amphibian boat used for weed control work.
Photo: Danielle Hancock, Waitakere City Council

General view of the wetland central water body, looking upstream.
Photo: Danielle Hancock, Waitakere City Council

Wetland edge showing emergent native vegetation among controlled willow saplings. Photo: Danielle Hancock, Waitakere City Council

A patch of sprayed alligator weed with willows in the background.
Photo: Danielle Hancock, Waitakere City Council



A stretch of water once was covered in Mexican waterlily. Parrot's feather now unfortunately dominates. Photo: Danielle Hancock, Waitakere City Council

CASE STUDY

CONTROLLING CRACK WILLOW IN TE HENGA/BETHELLS WETLAND

At 153 ha, Te Henga is the largest freshwater wetland in the Auckland region. The wetland is of national importance for wildlife, and supports a high diversity of freshwater wetland bird species and native vegetation. However, crack willow (*Salix fragilis*) has invaded the wetland, forming dense stands that totally exclude native vegetation, and has blocked water channels causing localised flooding and erosion. Grey willow (*S. cinerea*) is sparse throughout the swamp but has the potential to invade the majority of the wetland. The desired outcomes of the Waitakere City Council led restoration project are long-term flood control and enhanced wetland habitat for native plants, fish and birds.

Ground and aerial control

Crack willow control work started from the top of the catchment working downstream to avoid reinvasion from fragments broken off accidentally during work or through natural events. Over a 10-year period, willows in the main wetland body and channels were accessed by boat, and trunks were drilled and injected using a herbicide mix (1 L Roundup Renew extra, 10 g Escort, 20 mL Pulse, 2 L water) or seedlings and saplings foliar sprayed (1.5% Glyphosate).

Aerial treatment of willows was considered for the Mokoroa Arm portion of Te Henga wetland as it is a dense and inaccessible area. Consultations with individual landowners, a public meeting, and an open day were held as part of the resource consent process. A small pilot area was used for the initial aerial treatment. Willows were aerially mapped before aerial spray control to define areas suitable for boom spraying and those needing spot spraying (i.e. individual plants/small clusters surrounded by native vegetation). Glyphosate Green™, approved and recommended for use over water, was used for both treatment methods.

Monitoring

Vegetation monitoring plots were established in the wetland to track the results of the aerial spray work. As well as measuring willow control, any effects on non-target vegetation (e.g., native species) will be assessed, and the success of natural native regeneration evaluated.

Willow control – the benefits

- Water flow opened up from previously willow-choked channels
- Flooding reduced by allowing water to spread through the wetland
- Native regeneration where dead willow trees were left standing
- Greater recreational use of the wetland for locals (e.g., kayaking)

Willow control – the drawbacks

- An explosion of the aquatic weed parrot's feather (*Myriophyllum aquaticum*) due to more light penetrating the water
- Pampas (*Cortaderia* spp.) and other weeds invaded where dead willow trees were removed

Funding

To date, more than $320,000 has been spent on weed control, with joint funding from the Auckland Regional Council, Waitakere City Council and Rodney District Council, and assistance from the Department of Conservation. Agency support has been crucial: complete willow eradication requires a high level of coordination and individual landowners within the catchment lacked the resources to fully support such a large-scale conservation initiative.

REF: www.waitakere.govt.nz/cnlser/pw/greennetwk/pdf/tehenga-willow-control-report.pdf

6 Monitoring

Monitoring is important to record progress made, to evaluate the success of weed control, and to feed back into wetland management decisions. Monitoring data allows measurement of what actually happened compared with general targets for weed control, such as reducing the area occupied by introduced plants from 25% to 10% of the wetland.

Part of evaluating success is to look at what species replace the treated weeds. Are native plants colonising or weeds – either a new population of the weed (seed bank or invasion from nearby plants) or invasion of a different weed that requires follow up control? Your wetland system will show recovery in 1–2 years for small, targeted weed control, such as individual plant treatment, compared with 4–5 years or more for an aerial spray operation. Recovery will also happen in phases. Initial colonisers are likely to be fast-growing, light lovers such as annual plants and grasses. These are followed by sedges and rushes and finally by shrubs and trees (if they are part of the wetland).

Along with weed maintenance, monitoring is an ongoing activity that you need to plan and for which you need to allow time. Chapter 13 – Monitoring includes further methods for monitoring restoration progress. Remember to make the monitoring regular and to keep good records.

NIWA is monitoring the results of management experiments for highly invasive weeds such as Manchurian wild rice. Photo: Paul Champion, NIWA

6.1 Maps and flagging tape

Maps and flagging tape are two complementary methods to monitor and document weed infestations at the restoration site. Infestations can be marked on a map and, as such, provide a visual record of weed location, etc.

Supporting documentation should include:

- Weed location (e.g., GPS coordinates and photos taken from strategic photo points – see below)
- Weed species and site identification code (e.g., species, infestation number if more than one site of same species and management zone)
- Method of control
- Timing of control
- Results of control

Flagging tape (a brightly coloured plastic tape) can be used to mark infestations at the restoration site. A permanent marker can be used to record information on the tape such as the name of the weed, site identification code, and amount of weed seedlings removed. Note that flagging tape may not last longer than a year in the field.

6.2 Photo points

To record changes visually from precise locations throughout the wetland, set up a series of photo points throughout the wetland. Use marker posts labelled with a number and an arrow to indicate camera direction to take the same view each time. Include photo points at the permanent plots by sitting the camera on one of the corner pegs. Take the photographs at the same time each year, preferably mid-late summer, to eliminate seasonal changes.

6.3 Permanent plots

Establish permanent plots, selected as representative of each main vegetation type, and monitor immediately before restoration starts and at intervals afterwards (yearly if rapid change is expected, less frequently for minor change). Aim for at least 3–5 replicate plots per vegetation type/habitat as these will provide baseline information. Plot size will depend on wetland structure and number of permanent plots established; use several plots of at least 2 m × 2 m or 4 m × 4 m quadrats in low vegetation, and larger sizes, e.g., 5 m x 5 m or 10 m x 10 m for taller vegetation and/or fewer plots. In areas that have been completely transformed by weed removal, cleared land, new soil surface, etc., set up the plots immediately after planting.

The basic parameters to use are:

- Species composition
- Species cover
- Species height

For more detailed monitoring information on how to sample vegetation, soil and water parameters, follow the Wetland Condition Handbook methodology and fill in the Handbook plot sheet (see weblink at the end of the chapter). Add any additional monitoring components specific to your wetland.

DOC Aerial herbicide willow control trials in 2001 at Kopuatai peat dome, Waikato. Monitoring results show that limited damage occurred to native understory vegetation though seedling and sapling grey willows have re-established. Open areas of willow have been colonised by native sedges, invasive grasses and annual weeds. Photo: David Stephens (with permission from DOC)

6.4 Transects

Transects may be used instead of, or in addition to, permanent plots to monitor vegetation changes over time. A transect is a straight line, usually using a tape measure, that is placed along a gradient, such a decreasing water table, that causes different vegetation types. The length and location of your transects will depend on the physical drivers of the wetland and the resulting vegetation communities. For example, at a lake with wetland vegetation, the transect would run on a compass bearing (or at right angles) from the dry land margin, through the wetland to the lake.

When establishing or monitoring the transect, a tape measure can be attached to a fixed post and run out on a bearing and pulled in once completed. Alternatively, two fixed marker posts, each labelled with a compass bearing, can be used to mark the start and end of an established transect. The width of vegetation recorded either side of the transect line will depend on wetland structure – use 1 m or 2 m in low vegetation and 5 m or 10 m for taller vegetation.

The basic parameters to record are:

- Species composition
- Species cover
- Species height
- Species maximum distance along the transect

Monitor immediately before restoration starts and at intervals afterwards (yearly if rapid change is expected, less frequently for minor change). Add any additional monitoring components specific to your wetland.

Vegetation transect line. Whakamaru, Waikato. Photo: Kerry Bodmin, NIWA

6.5 Aquatic plant monitoring

Although terrestrial monitoring is easier, finding out what aquatic species exist in underwater areas of the wetland is just as important. Donning a wetsuit and snorkel, or a drysuit and snorkel as the team has in the picture below, reveals a whole new world of submerged plants in shallow waters and margins and can be a fun activity in hot summer months.

The tools used for submerged plants, otherwise known as macrophytes, are similar to those described above, combined with indices to assess and monitor submerged vegetation. Where streams or channels enter a wetland the rapid assessment guidelines developed by Environment Waikato can be used to assess macrophyte cover. The extent of aquatic plant cover along five transects can be measured and scored to give an index of total plant cover over the stream bottom, an index of plant cover through the water column, and an index of the naturalness of the macrophyte community (Collier et al. 2007).

In shallow waters, transects may be established in a similar manner to those used in emergent wetland vegetation. Transects run along the water gradient, from shallow margins into the depths. A width of 1 m or 2 m is commonly used to record vegetation either side of the transect line including species, cover, maximum depth and maximum height – the latter can be measured using a weighted tape measure.

Where a wetland borders a deep water body, the LakeSPI method (see links to useful websites at the end of the chapter) can be used to assess and monitor the ecological condition of the lake through submerged plant indicators (SPI). Divers record information on both native and exotic submerged plants, including species, cover, maximum depth and maximum height, over several transects; usually five transects are recommended. A simple scoring sheet provides a description of the condition of native vegetation (native condition index), the condition of submerged weeds (an invasive condition index), and the overall ecological state of the lake (lake condition index). Any change in these indices can be monitored over time for a particular lake and also compared with other lakes throughout New Zealand.

Carrying out Lake SPI monitoring at Lake Waikaremoana, East Coast/Hawke's Bay. Photo: John Clayton, NIWA

Snorkelling can also be used in shallow water wetlands to gain a better understanding of the species present and the ratio of native aquatic plants to introduced species. Lake Ngatu, Northland.
Photo: Kerry Bodmin, NIWA

7 References and further reading

Champion P., James T., Popay I. and Ford K. 2012. *An illustrated guide to common grasses, sedges and rushes of New Zealand.* New Zealand Plant Protection Society, Canterbury, New Zealand.

Collier K., Kelly J. and Champion P. 2007. *Regional guidelines for ecological assessments of freshwater environments: Aquatic plant cover in wadeable streams.* Environment Waikato Technical Report 2006/47.

Johnson P.N. and Brooke P.A. 1989. *Wetland plants in New Zealand.* DSIR Publishing, Wellington, New Zealand.

Popay I., Champion P. and James T. 2010. *An illustrated guide to common weeds of New Zealand*. 3rd ed. New Zealand Plant Protection Society, Canterbury, New Zealand.

7.1 Useful websites

Wetland restoration templates

Waikato Regional Council Wetland Restoration Plan templates

www.waikatoregion.govt.nz/PageFiles/5799/Wetlandtemplate1.pdf

www.waikatoregion.govt.nz/PageFiles/5799/Wetlandtemplate2.pdf

Wetland restoration guides and factsheets (New Zealand)

Northland Regional Council

www.nrc.govt.nz/upload/2217/Wetland%20Restoration%20Guide%20(second%20edition%20Feb%2009).pdf

Auckland Regional Council

www.arc.govt.nz/albany/fms/main/Documents/Environment/Plants%20and%20animals/wetlandsfacts2.pdf

Waikato Regional Council

www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Freshwater-wetlands/

Hamilton City Council

www.gullyguide.co.nz/index.asp?pageID=2145821537

Bay of Plenty Wetlands Forum

www.doc.govt.nz/upload/documents/conservation/land-and-freshwater/wetlands/wetland-restoration-guide.pdf

Greater Wellington

www.gw.govt.nz/a-beginner-s-guide-to-wetland-restoration/

Department of Conservation Protecting Natural Areas Design Guide

www.doc.govt.nz/publications/getting-involved/volunteer-join-or-start-a-project/start-or-fund-a-project-/nature-heritage-fund/protecting-natural-areas-design-guide/

Wetland restoration guides (International)

USA Environmental Protection Agency

www.epa.gov/owow/wetlands/pdf/restdocfinal.pdf

Introduced plant identification resources

NZ Plant Conservation Network

www.nzpcn.org.nz

NIWA aquatic quick guides for flora and fauna

www.niwa.co.nz/our-science/freshwater/tools/quickguides

Landcare Research

www.landcareresearch.co.nz/resources/identification/plants/weeds-key

Weedbusters

www.weedbusters.co.nz/

Priority weed lists

Biosecurity N.Z.

www.biosecurity.govt.nz/pests/surv-mgmt/mgmt/prog/nipr

Auckland Regional Council

www.arc.govt.nz/environment/biosecurity/pest-plants/pest-plants_home.cfm

Environment Bay of Plenty

www.boprc.govt.nz/environment/pests/pest-plants-and-weeds/weed-index

LucidKey for National Pest Plant Accord weeds

www.landcareresearch.co.nz/resources/identification/plants/weeds-key

Weeds control methods

Weedbusters

www.weedbusters.co.nz

Willow control

www.arc.govt.nz/albany/index.cfm?63E0F20E-14C2-3D2D-B905-50098EBBE4B9&plantcode=Salcin

Herbicide use

www.arc.govt.nz/environment/biosecurity/pest-plants/herbicides.cfm

Certification for herbicide use

www.growsafe.co.nz

Botanical Societies

www.nzbotanicalsociety.org.nz/pages/links.html

Herbaria in New Zealand

www.nzherbaria.org.nz/herbaria.asp

NZ Journal of Botany

www.tandfonline.com/loi/tnzb20

Note that many of the resources above are available as hard copy from the respective organisations. There is also a CD containing all above hyperlinks at the back of this Handbook. If you are using the online version of the Handbook and having problems with the hyperlinks above, try copying and pasting the web address into your browser search bar.