Willows: friend or foe? A national approach to willow management in Australia

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Abstract

Willows (*Salix* spp.), familiar icons of the Australian landscape, are listed as one of Australia's 20 Weeds of National Significance (WoNS), due to their highly invasive nature and negative impacts on stream and wetland hydrology and biodiversity. Although listed as one WoNS, there are more than 30 naturalised willow taxa in Australia and over 300 taxa worldwide. As some willows can spread long distances by seed across regions and states, national coordination is proving critical to ensure management is effectively coordinated between areas. Lack of knowledge of the extent and impact of different willow species, however, impedes effective management. To prioritise willows for management at the national, state and regional levels, the National Willows Program has conducted a detailed weed risk management process, with input from over 650 people across Australia. To further improve management, a detailed national management guide and resource kit have been developed, several research projects undertaken and a national information sharing network established. This paper outlines some of the outcomes achieved by the National Willows Program to date, the processes used to achieve

such outcomes, and how these can be utilized by regions, states and other nations in protecting and improving their waterways for the future.

1. Introduction

Willows (*Salix* L.) were originally introduced to Australia from Europe, Asia, North America and South America for basket making, cricket bat production, stream stabilisation, ornaments and shelter. Planting began soon after European settlement and was most extensive from the 1950s to 1970s to help control stream and gully erosion and for use as windbreaks. During this time, willows became a familiar icon of the Australian landscape.

During the 1980s and 1990s, the problems with willows became more broadly recognised and a relatively dramatic shift in waterway management occurred. Now, the same trusts and boards that originally advocated their use often conduct extensive willow removal operations (ARMCANZ, ANZECC & FM 2001). The reason for such a profound shift in perspective was the mounting evidence of the impacts that willows cause to both aquatic and riparian environments and their ability to so readily and aggressively colonise new areas.

Attempts to remove willows from along waterways are still often met with strong community opposition (e.g. Andrews 2006), but there is also growing opposition to leaving them unchecked. In reality, neither the retention nor control of all willows is necessary, feasible or desirable. Instead, effective decisions need to be made about why, when, how and where to manage them.

A National Willows Program was established in 2005 in order to guide the strategic management of willows across Australia. At the heart of the program is the desire to build an objective, evidence-based approach that recognises the complex nature of willows and their management. To do this, the National Willows Taskforce has had to manage conflicting views and attempt to interpret contradictory information on almost every aspect of willow management. This paper outlines some of the key outcomes achieved by the National Willows Program to date, the processes used to achieve such outcomes, and how these can be utilized by regions, states and other nations in protecting and improving their waterways for the future.

2. The problem

Willows are an extremely complex group, which pose a significant and unique challenge to the conservation and rehabilitation of many of Australia's temperate rivers and wetlands. For example, the number of different willow taxa and their ability to rapidly disperse and to hybridise complicates our ability to manage them, as does their utilitarian and cultural value.

The genus *Salix* (willows) is a taxonomically complex genus, comprising 3 recognised subgenera and more than 400 species, subspecies, varieties, hybrids and cultivars worldwide (van Kraayenoord *et al.* 1995). Of these, over 100 taxa have been introduced into Australia and eleven species, twenty-five subspecies and numerous hybrid combinations are known to be naturalised (ARMCANZ, ANZECC & FM 2001; APC 2007; DEH 2007).

Different willows vary in their ability to spread into and thrive in new environments. How willows spread has significant implications for how they need to be managed. Willows can spread by seed germinating on bare, wet sediments, or by branches, attached or detached, taking root on wet ground or in shallow water. Some willows mainly disperse by one of these methods, while others will easily spread by both means.

Willows also have a remarkable ability to form hybrids, making accurate identification difficult (Cremer 1995). Almost all willow taxa are capable of hybridising with one or more other taxa if they flower at the same time and fertile male and female plants grow near enough for pollination to occur. At least 10 willow taxa have already demonstrated the ability to cross with other taxa and form viable, naturalised hybrids in Australia (Steel *et al.* 2008). While some resulting hybrids may not flourish, some have become apparently more invasive than their parents and there is the potential for strains to develop that are even better adapted to local conditions within Australia (e.g. hybrids of *S. babylonica* weeping willow, Cremer 2003, Gehrig *et al.* 2006).

The ability of willows to hybridise and spread long distances by seed highlights the national significance of the willow problem. Whereas the dispersal of vegetatively reproducing willows is generally confined to the specific streams where they grow, the great mobility of some seeding willows requires that effective control be coordinated across regions and states (Cremer 2001). A female willow can release thousands of seeds each spring. Although these seeds are relatively short-lived (surviving just a few weeks), germination can be rapid (taking just 6-8 hours) and some willows have been known to spread seed by wind up to 50-100 km from their parent plant (Cremer 2003).

The spread of willows provides a particularly challenging issue to waterway managers where there is a potential threat from willows that occur outside their planning zone. For example, it may be necessary to control seeding willows in areas where they do not currently cause significant impacts (e.g. in parks and gardens or even adjacent catchments), to prevent them from spreading to other, more important environments (e.g. along rivers or wetlands).

Willow management is also complicated by the actual and perceived values and impacts of willows, the expense, risk and difficulty of conducting control and the numerous policies and regulations that influence management. For example, controlling willows can be a very dangerous activity and, if done poorly, may result in more damage than good. Also, removing dense stands of willows is likely to have affects on stream dynamics, including impacts on the morphology and water quality of the stream (Zukowski and Gawne 2006). Appropriate management strategies will therefore vary from site to site, according to the relative influence of factors such as the extent, type and location of the willows, ecological and physical characteristics of the waterway, catchment, regional, state and national influences and social, economic and legal constraints.

3. A National Willows Strategic Plan

In 1999, all willows (except *S. babylonica*, *S.* x *calodendron* and *S.* x *reichardtii*) were listed as one of Australia's 20 Weeds of National Significance (WoNS). To help guide national coordination, the *National Willows Strategic Plan* was developed (ARMCANZ, ANZECC and FM 2001), with three primary aims: stop further spread of willows; manage the existing areas of willows; and gain community support in managing the willow problem.

3.1 National Willows Taskforce

A National Willows Coordinator was appointed in April 2005 and the National Willows Taskforce (NWT) established in August 2005 in order to facilitate implementation of the Strategic Plan. The National Willows Taskforce consists of 12 representatives from State, Territory, Federal and Local Governments, Catchment Management Authorities, the Cooperative Research Centre for Australian Weed Management, the Nursery and Garden Industry of Australia and the community. It provides key linkages across regions and States to ensure a coordinated, cross-

regional approach to on-ground management. It also fosters a shared approach to research, improving management techniques and developing education and awareness materials.

From 2005 to 2007, the taskforce focused on reviewing progress that had been made, building effective partnerships and networks across Australia, identifying research, communications and on-ground management priorities and initiating major projects needed to address these priorities.

Key progress achieved towards the *National Willows Strategic Plan* to date includes:

1. Improving our understanding of the current and potential extent and impacts of willows (including non-naturalised cultivated willows) and where to focus management through mapping their known extent and conducting a detailed weed risk assessment to identify high risk species.
2. Developing a sound, evidence-based process for setting on-ground priorities at national, state and regional levels and providing a benchmark for future progress.
3. Increasing engagement of the Nursery and Garden Industry Australia through their active involvement in the weed risk assessment of willows.
4. Increasing the awareness, aspirations and skills of more than 600 people across Australia through a series of training workshops and resource materials.
5. Improving our understanding and raising awareness of the potential threat of willows beyond the historical geographic focus areas (i.e. to Queensland and Western Australia).
6. Assessing and improving management and control methods through research and development activities and development of a *National Willows Management Guide.*
7. Continued suppression of invasive willows through the development and implementation of active management programs.
8. Increased investment in cross-border, strategic willow management programs by organisations across Australia.
9. Increased access to information relating to willows and their management via the Weeds Australia website and National Willows Network e-groups.

A detailed analysis of these outcomes and the processes used to achieve them is presented in the remainder of this paper. Although all actions have combined to achieve the above outcomes, outcomes 1-5 have primarily been achieved through conducting weed risk assessments of naturalised and non-naturalised cultivated willow taxa and outcomes 6-8 have mainly been achieved through assessing and improving management and control methods.

3.2 Weed risk assessments of naturalised and non-naturalised willow taxa

In the determination of the WoNS, willows were nominated, assessed and listed as an entire genus, with the exception of three taxa (Thorp and Lynch 2000). Since then, new research and information has highlighted the need to understand and prioritise management based on specific species, varieties, cultivars and hybrids.

When the National Willows Taskforce was established, information on the current and potential extent and impacts of different willow taxa across Australia was extremely limited. This was recognised as a major drawback to being able to objectively prioritise management actions. The taskforce therefore conducted a detailed weed risk management process, with input from over 650 people across Australia, to enable effective priorities to be developed at the national, state and regional levels (Steel *et al.* 2008). This process provides a more objective basis than was previously possible for determining which willows require control and which, if any, may be considered safe enough to leave *in situ* or even continue to be planted.

3.2.1 Process

A standardised risk management process was adopted in accordance with the National Post-Border Weed Risk Management Protocol (SAI 2006). This protocol outlines a standard process that seeks to obtain relative rankings on weed risk and control feasibility, as a decision support tool for allocating resources in weed management. It considers the following three key components:

1. invasiveness (intrinsic ability to establish in suitable environments),
2. impacts on social, environmental and economic values and
3. present to potential distribution (how much further each taxon could spread).

Given that there are over 400 taxa world wide, it was not feasible to assess the weed risk of all willow taxa individually. An objective process was therefore adopted to determine which taxa, or groupings of willows, would be assessed. Taxa were selected for assessment if they had been introduced to Australia and met one or more of the following criteria:

1. Each of the three *Salix* subgenera: *Salix, Vetrix* & *Chamaetia* (according to the taxonomy of Skvortsov, 1999); the tree, shrub and alpine willows.
2. All naturalised species and named hybrids.
3. Willows not naturalised in Australia that:
    a. have become naturalised far beyond their native range, especially those that are naturalising in New Zealand and Oceania, where *Salix* is absent from the native flora,
    b. exhibit invasive traits such as forming dense thickets, or
    c. were suspected of having a low weed risk.
4. Willows exempt from noxious weeds legislation.

The list of taxa was posted on the web and sent out broadly for public comment and any requests for additional taxa to be added to the list were considered.

At an horticultural media forum held in May 2006, concern was raised about an entire genus (e.g. *Salix* spp.) being declared as noxious weeds in Victoria, with few exceptions. This concern highlighted the need for greater consultation with this industry in the planning and implementation of a weed risk assessment process for any weed. Such consultation has clear benefits for the growers, by giving them the opportunity to contribute their knowledge and expertise and to develop an understanding of why certain legislative decisions are being made. It also benefits the weed risk assessment as growers are able, in some cases, to provide additional knowledge of taxa that have little published information about them.

To invite input from the Nursery and Garden Industry Australia (NGIA), two articles were included in their newsletter, e-Clippings, and an email was sent via the Victorian peak body to all members. In addition, all growers listed in the Aussie Plant Finder as having sold willows were directly contacted and asked if they still sell or want to sell any willows, and if they would like to add any taxa to the proposed assessment list. The final list was then officially approved by the NGIA representative on the National Willows Taskforce.

In total, thirty-five willow taxa were assessed, including the three subgenera. The three subgenera were assessed as generic groupings, as taxa within a subgenus often share many biological and ecological traits.

<u>3.2.1.1 Invasiveness and impacts</u>

Each taxon was assessed against fifteen invasiveness and ten impacts criteria questions. These criteria are a set of multiple choice questions, with the choices referred to as 'intensity ratings', which range from low to high. The intensity ratings allocated to each question for each taxon were determined using a range of information sources, including refereed journals, books, expert opinion and the internet. Assessment of the genus *Salix* compared to other weeds had already been conducted as part of the original WONS process (Thorp and Lynch 2000), and 16 willow taxa had been assessed using the Victorian Pest Plant Prioritisation Process (Weiss and McLaren 2002). Both of these processes complied with the Australian standards, but their main functions were to differentiate amongst the wide range of plants nominated as candidate WoNS and noxious weeds respectively. Rather than comparing willows with other plants, a major focus of these new assessments was to identify and prioritise management of the most invasive willow taxa.

Many of the criteria previously used to assess willow taxa were not able to discriminate between different willows. For example, in the Victorian assessments, the 16 willow taxa assessed received the same rating for 13 out of 26 impacts criteria questions (see Figure 1). In addition, all willows rated either H or MH for question 11 and either L or ML for question 19.

The invasiveness criteria used in the Victorian assessments were much better at discriminating between willow taxa. Thirteen of the fifteen invasiveness criteria were therefore also used in the national assessments without amendment. Two reproduction questions that showed little variation (questions 11 and 12) were replaced by new willow-specific questions to consider the risks of hybridisation and the propagule pressure associated with planting types of willows *en masse*, as a single specimen, or somewhere in between (Table 1).

Table 1: New invasiveness criteria developed specifically for willows, to replace questions 11 and 12 from the Victorian Pest Plant Prioritisation Process (Weiss and McLaren 2002).

New criteria	Intensity ratings			
	Low	**Medium low**	**Medium high**	**High**
11. Hybrid facilitation. Hybridisation is assessed based on taxa that have been introduced to Australia. Ability to produce viable propagules.	Very unlikely to hybridise with a naturalised willow.	Cultivation has produced hybrids between this taxa and a naturalised willow taxon.	Able to hybridise with a naturalised willow in the wild. Enables a cultivated willow to produce viable offspring (by providing a pollen or egg source).	Evidence that the taxon is the parent of a naturalised hybrid.
12. Proximity of plantings.	Willow grown only in floriculture for foliage/catkins/ stems.	Specimen tree or shrub, usually only planted as a single specimen.	Fodder or shade tree that may be planted in larger numbers.	Willow commonly used as a windbreak, erosion control or avenue tree. Large scale plantings.

To better differentiate among the willow taxa, the taskforce decided that a unique set of impacts criteria questions were required. To develop criteria that best reflected the range of social, economic and environmental values that willows most impact upon, a workshop was held with fifteen people with different perspectives and expertise from across Australia. Participants had expertise in willows, biodiversity, agriculture, horticulture, weeds and/or water and worked in a range of areas, including business, research, extension, policy and on-ground management. Two representatives of the NGIA attended the workshop. Following the workshop, the new criteria were circulated to participants and other interested persons for additional comment. A paper was developed in response to all comments received and the criteria were refined and distributed for final comment.

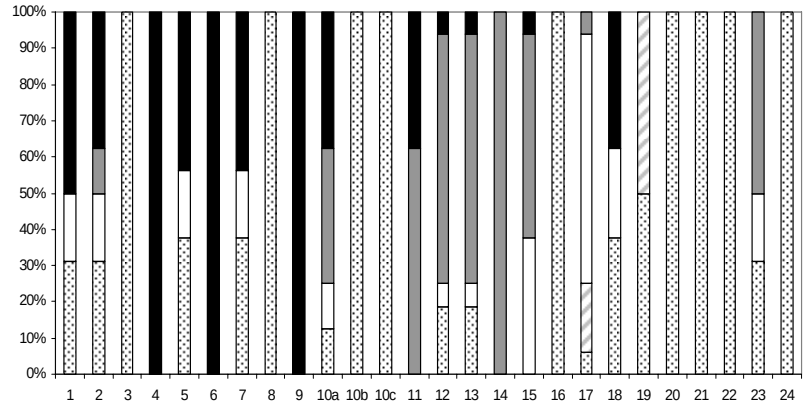
Ten impacts criteria questions were developed (Table 2), each with descriptors for either three or four intensity ratings (L, ML, MH and H). These 10 criteria were much more effective in discriminating between taxa than the generic Victorian criteria, with a spread of ratings from low to high being given for each criterion, as indicated in Figure 1. In all cases, the 'worst-case scenario' was used, to reflect the full potential for the plant to have an impact. For example, if there was evidence that a willow was capable of having a large impact in a particular environment it was given a high rating, even if its impact is lower in other types of environments.

Table 2: New impacts criteria developed for the national willows risk assessment and the weightings, or relative importance, given to each criteria

Criteria (weightings)	Intensity ratings			
	Lowest threat L	**ML**	**MH**	**Highest threat H**
Socio-economic (12%)				
1. How much damage could be caused to human built infrastructure? (39%)	Visual effect; little to negligible structural damage.	Able to be remedied as a normal part of everyday maintenance (e.g. pruning).	Maintenance requires specialised equipment, such as for clearing drains or drainage channels.	Major damage to bridges, culverts, weirs, dams, etc. requiring repair.
2. How much amenity value does the willow have? (15%)	Attractive/useful foliage/catkins/stems; **OR** valued as a fodder, shade, wood, windbreak or avenue tree; **AND** require knowledge to propagate, **AND** are single-sex clones	Attractive/useful foliage/catkins/stems; **OR** valued as a fodder, shade, wood, windbreak or avenue tree; **AND** require knowledge to propagate.	Some horticultural/agricultural value, but easy to propagate, bisexual or male and female, naturalised in Australia.	No aesthetic value, easy to propagate, bisexual or male and female, naturalised in Australia.
3. To what extent could the willow impact on the health and safety of waterway/ riparian users? (7%)	Little to no impact on public safety. Willow is low-growing and/or has branches that are too thin to cause serious health damage.		Moderately likely to cause serious injury or death of waterway/riparian users (e.g. tree willow/tall shrub with large, but flexible branches).	Most likely to cause serious injury or death of waterway/riparian users. e.g. tree willow with brittle branches. Risk of death to water skiers.
4. To what extent could the taxon impact on recreation in/on waterways? e.g. swimming, boating (including canoeing, skiing, rafting), fishing, bird watching and passive enjoyment (e.g. picnics) (39%)	Little to no impact on activities. Willows not obvious to average visitors.	<4 activities affected, minor effects (e.g. willows able to form monocultures that reduce bird life and impede river views for passive enjoyment, but access for swimming, boating and fishing is still possible)..	4+ activities impeded(e.g. stream deep enough to boat/swim, but access impeded by willows on the bank).	4+ activities prohibited (e.g. willows encroach into stream, making it too shallow to swim/boat).
Stream health: water quality and aquatic biodiversity (56%)				
5. To what extent could the willow impact on the hydrology, i.e. flow of water in streams and water availability? (12%)	Little or negligible impact on flow capacity or water availability. Willow grows offstream with no root or stem growth in stream.	Minor impact of flow by roots or foliage. Roots sometimes grow instream. Capable of removing more water than vegetation lacking instream root systems.	Major impact on flow by roots and foliage including major root structure. Roots and stems often grow instream. Capable of using large quantities of water.	Always extensive roots and stems growing in stream, making them capable of using the most water.

6. To what degree could the willow cause bank erosion, i.e. changes to geomorphology? (68%)	Low probability of large scale soil movement. Does not grow in riparian areas.	Moderate probability of large scale soil movement. Terrestrial species that suppresses the understorey and lacks extensive root system, allowing erosion of the banks by overland runoff.	High probability of large scale soil movement, but effects remain in stream. Willow roots and stems encroach in stream to create a wider, shallower stream.	High probability of large scale soil movement and major off site implications and bank failure. Willows are confined to the banks, but under flood conditions the stream is diverted behind the willows, scouring out large areas of land.
7. To what extent could the willow affect water quality and, consequently, in stream native biodiversity, as measured by potential leaf fall? (20%)	Plant is low growing and unlikely to affect the shading of waterways or to drop many leaves into the stream **AND/OR** doesn't grow near waterways.		Grows along the bank to 4+m tall such that large amounts of leaf litter will fall into the stream and/or has the ability to cause unseasonal opening in the canopy by significantly outcompeting native vegetation.	Plant overhangs stream, or encroaches into stream such that most of its foliage will fall into the water. Weeping tree or prostrate form.
Biodiversity: aquatic and terrestrial (32%)				
8. To what extent could this willow affect riparian/wetland habitat structure/layers? *i.e.* ground (forbs, grasses, herbs), shrub and tree layers within an environment. (47%)	Minor or negligible effect on <20% of the floral strata/layers present; usually only affecting one of the strata **OR** not known as a weed anywhere in the world.	Minor effect on 20-60% of the floral strata. Does not form large thickets.	Minor effect on >60% of the layers **OR** major effect on <60% of the floral strata. Large thickets interspersed with other vegetation.	Major effect on all layers. Able to form monocultures; no other intact strata/layers present.
9. How many riparian habitats (in-stream, margins, banks, floodplain, wetlands) could be impacted by this willow? (47%)	Coexists with other vegetation in any of the riparian niches and is not dominant **OR** does not grow in riparian environments.	Occurs as the dominant species in any one of the riparian niches.	Occurs as the dominant species in any two of the riparian niches.	Occurs as the dominant species in any three of the riparian niches, **AND/OR** is capable of invading wetlands.
10. To what extent could this willow affect other invasive flora and fauna? (6%)	Suppresses (e.g. *Glyceria* sp.). No associations formed with other invasive species.	May occur in association with minor pests, such as blackbirds or non-declared weeds.		May occur in association with serious (declared) pests, such as rabbits, foxes or blackberry.

a)



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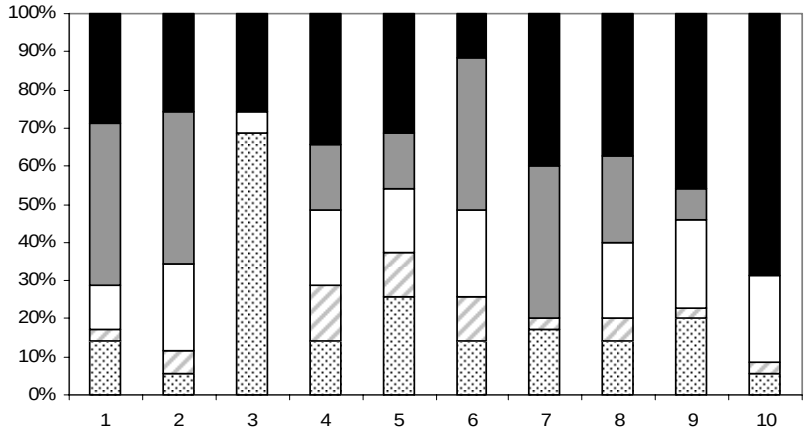

Figure 1: The proportion (%) of willows that scored low (L), medium low (ML), medium (M), medium high (MH) or high (H) for each of the impacts criteria used in a) the Victorian noxious weeds review (24 questions) and b) the National Willows Weed Risk Assessment (10 questions). L = dotted, ML = dashed, M = white, MH = grey or H = black. (From Steel and Scott 2007).

3.2.1.2 Present to potential distribution

The present to potential distribution (or potential for spread) plays an important role in prioritising taxa for management. For example, a plant with a small current distribution that has the potential to spread much further poses a much greater future risk than a plant that has already filled its potential range.

Prior to 2006, there was no centralised database detailing willow distribution data. Some electronic records could be found on the Australian Virtual Herbarium and in individual organisation's databases but, in general, very little data had actually been recorded.

To determine the current extent of willows across Australia, a standard mapping template and guidelines were developed and distributed via the National Willows Network e-group to over 300 people nationwide and placed on the web (www.weeds.org.au/WoNS/willows), with a request for all available willow mapping information. The template included a national list of core attributes developed for mapping all WoNS (Thackway *et al*. 2003), as well as several willow specific attributes that would assist in prioritising management efforts. Various existing data sets were also located and procured via contacts in each State and nationally, including data from State and national herbaria and government agencies.

It was recognised that, although little information on where willows exist had been formally recorded, considerable information existed in people's minds. Therefore, a series of workshops was organised and delivered to all willow affected regions across south eastern Australia, to collate and update mapping information. In addition, the workshops were used to train willow managers on the topics of identification, the willow sawfly and mapping, as these are all key skills needed for setting effective management priorities. When registering for a workshop, participants were also asked on their registration forms if they could provide us with any existing electronic mapping data. All mapping data collected prior to workshops was used to generate a map for workshop participants, to indicate which parts of the region had already been mapped, and direct participants to focus their efforts on filling the gaps.

At each workshop, acetate sheets were placed over 1:50,000 or 1:100,000 topographic maps covering the respective region and participants were asked to mark on these maps where they knew willows were either present, had been controlled or have never been present, using a methodology and classification system adapted from *Strategic Planning for Willow Management in Tasmania* (Farrell, 2003). The eight class classification system included three density classes (occasional or scattered willows; scattered stands with isolated trees interspersed; large dense infestations), each with two broad vegetation types (mostly native vegetation in good or excellent condition; mostly weeds, grass or native vegetation in poor condition), plus a class each for willows treated and/or removed and no willows present. Participants drew on the acetate sheets using 8 different coloured pens to represent the 8 infestation classes and added adjacent notes where additional information was known. The maps with the acetate sheets still overlaid were left in the region for at least one month after each workshop to enable people to add further information to them. The request for any available electronic data was repeated at each workshop and additional data sourced as a result.

In total, twenty-nine willows workshops, attended by a total of 576 people, were held across twenty-nine CMA or NRM regions in Victoria, New South Wales, Tasmania, South Australia and the Australian Capital Territory between September 2006 and March 2007 (see Figure 2).

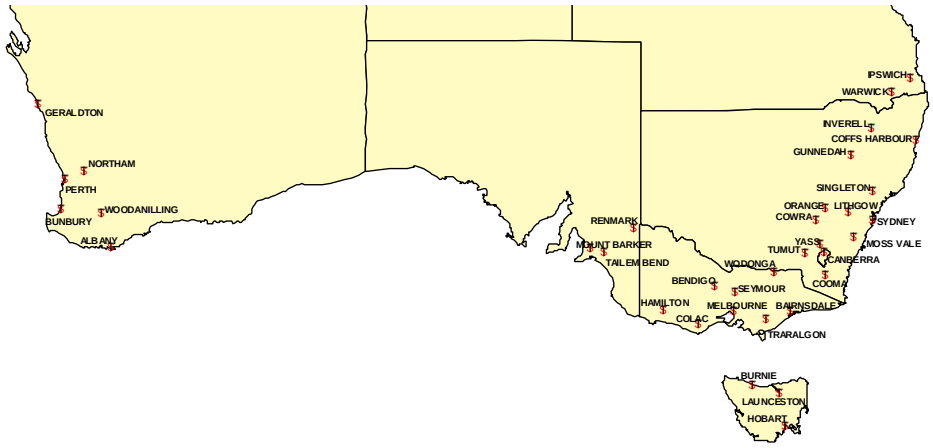

Figure 2: Location of the 29 regional willows workshops held across southeastern Australia and the 9 awareness raising presentations given in Queensland and Western Australia.

Anyone involved in willow management, or with an interest in willows within a region, was invited to attend a workshop; including contractors, regional catchment management and river health officers, Landcare and 'Friends of…' groups, parks rangers and state and local government weeds and native vegetation officers. Each participant was given a National Willows Program Resource Kit (Holland Clift *et al.* 2006), which was developed specifically for the workshop series and contained relevant information on the above topics (also available for download at www.weeds.org.au/wons/willows).

The workshops were seen as a cost-effective method for collecting broad information on willow distribution across Australia, as well as training participants in the key skills required for them to more effectively map and therefore manage willows within their regions. Through a detailed evaluation of the workshops (Wadley and Holland Clift 2007), it was clear that they played a major role in

- increasing the knowledge, attitudes, skills and aspirations of over 570 willow managers across Australia,
- creating and/or updating regional maps highlighting where willows occur and generating further interest in mapping willows,
- enhancing willow practitioner networks on a national and regional level, with an average of 20 participants and nine organisations represented at each workshop, and
- the discovery of new populations of highly invasive seeding willows in northern New South Wales and throughout South Australia.

Originally, 20 workshops were planned but, due to the large level of interest received, an additional nine workshops were required. This indicated a heightened level of awareness of willows across Australia. In addition, at least five extra workshops were planned and run by workshop participants using the resource materials developed for the workshop series. The information and key messages delivered, therefore, continued to be passed on to other people within these regions beyond this initial workshop series.

Following the workshops, participants were sent a mapping brief, excel spreadsheet with preferred mapping attributes and regional map with known willow distribution records. Using these, they were asked to conduct on-ground mapping over the following spring, when willows were in flower, to gain further data for their region. The impetus was on local officers to ensure the data for their region was as accurate as possible, so that the recommendations made from the weed risk management process would be most useful to their region. Additional data was procured as a result.

Although there are few willows known to occur in Western Australia and Queensland, a preliminary weed risk assessment revealed the potential for willows to become problems in these two States, if certain willow taxa become established. However, there was insufficient awareness of and interest in willows at this time to warrant conducting full workshops in these States. Instead, two presentations were given in southeast Queensland and 7 in southwest Western Australia in conjunction with other weeds forums, to raise awareness of the potential threat of willows and request assistance in identifying areas for on ground mapping.

In the following spring, when willows were in flower, the National Willows Program conducted targeted, on ground mapping in the following areas, to identify both the taxon and sex of each willow found:

- Southeast Queensland, including areas around Warwick, Gladstone, Brisbane and Stanthorpe.
- Northeast New South Wales, including areas around Tenterfield, Casino, Spring Grove, Lismore and Bonalbo.
- Southwest Western Australia, from Geraldton in the north to Albany, Augusta and Esperance in the south.
- South Australia, along the River Murray and the Fleurieu Peninsula (*S. cinerea* and *S.* x *reichardtii* only).

These areas were selected as national mapping priorities based on:

- the known outer most ranges of each naturalised willow taxon, to confirm the current climatic limits of each taxon for the weed risk assessment, and
- the locations of Ramsar-listed wetlands that may be at potential threat by willow invasion, to enable national prioritisation based on high priority assets.

Local and State government weeds and biodiversity officers assisted in finding locations and collecting on ground data. Specimens were collected and lodged at the relevant State herbaria and were also identified by taxonomic expert Geoff Carr of Ecology Australia.

All of the mapping data collected was collated, digitised where necessary and added to a GIS database. Potential distribution maps were also incorporated into the GIS database, along with geospatial references such as towns, roads and waterways.

The potential distribution of each taxon was determined using a climate analysis that was then constricted to suitable habitat types. For each taxon, current distribution data from Australia and overseas (including both native and introduced ranges) was analysed using *CLIMATE* (Pheloung 1986) software, to determine suitable climates within Australia for naturalisation to occur. Data from outside Australia was sourced from the Global Biodiversity Information Facility (GBIF) and literature such as Floras. A literature search was conducted to determine suitable habitats for each taxon and *ArcGIS 9* was then used to refine the climate match to suitable habitat types, according to the National Vegetation Information System (DEWR 2007).

A series of layered PDF maps were created that enable the data to be displayed at different scales appropriate for national, state and regional planning. The layers of the PDF can be easily turned on or off to display a combination of present and potential distributions of one, several or all willow taxa, as well as locations where management has occurred. This data now forms the basis for our current knowledge on willow distribution across Australia.

3.2.1.3 Calculating the assessment score

A distribution score was allocated to each taxon based on the ratio between their present and potential distribution, using the Victorian Pest Plant Prioritisation Process (Weiss and McLaren 2002). Each taxon was assessed at a national scale and for each Catchment Management Authority and Natural Resource Management region across Australia.

Invasiveness and impact scores were calculated by converting the intensity ratings to numerical scores, where H = 1, MH = 0.67, ML = 0.33 and L = 0. Different criteria were considered more important than others in determining the risk of willows. Weightings were therefore assigned using an Analytical Hierarchal Process to each of the three components (invasiveness, impacts and present to potential distribution) and to each criterion within the invasiveness and impacts components according to their relative level of importance to overall weed risk. The weightings developed for the Victorian Pest Plant Prioritisation Process were used for the three components and invasiveness criteria (Weiss and McLaren 2002), and an additional workshop was run to assign weightings for the new impacts criteria (see Table 2). The weightings assigned for invasiveness, present to potential distribution and impacts were 12%, 32% and 56% respectively. Therefore, the overall score for each taxon was calculated by: Weighted invasiveness score x 0.12 + weighted impact score x 0.56 + distribution score x 0.32 = total score.

Confidence scores were also calculated for each assessment, based on the quality of information that was used (Weiss and McLaren 2002). Ratings of high (H), medium high (MH), medium low (ML) and low (L) were given for different information sources (e.g. ‘peer-reviewed scientific papers’ were rated as high and ‘no data or reference material available’ as low and other sources rated in between) and then converted into the following numerical scores: H=1, MH=0.67, ML=0.33 and L=0. If there was insufficient evidence available to answer a question for a particular taxon, it was given a rating of medium (M), with a value of 0.5, and a confidence score of low (L). This is because a medium rating is likely to cause the least error since it can

only be inaccurate by a maximum of +/-0.5, but there is little confidence that medium is the true rating that question should be given.

To prioritise taxa for management based on their feasibility of control, each taxa was given a prioritisation level from 'very high' to 'low'. These were determined by comparing combined impacts and invasiveness scores with present to potential distribution scores and can be defined as:

- Very high priority: High invasiveness and impact risk; either not yet naturalised, or eradication is feasible.
- High priority: High invasiveness and impact risk; high potential for spread.
- Medium priority: Medium invasiveness and impact risk; either a high potential for spread, or able to be eradicated.
- Low priority: Low invasiveness and impact risk; either has already spread across a large part of their potential range, or are unlikely to establish due to unsuitable climate.

3.2.2 Key results

The following results and recommendations relate primarily to the national perspective. Although not presented in this paper, a regional ranking, prioritisation matrix and series of current and potential distribution maps of different willow taxa were also developed for each Catchment Management Authority or Natural Resource Management region in Australia. These maps can be scaled down and the risk assessment information adapted to local levels to help plan where to focus surveillance and management efforts within specific areas.

A total of 21 willow taxa are now known to infest at least 21,015 ha in 38 Catchment Management Authority or Natural Resource Management regions in all States and Territories except the Northern Territory (Table 3). *Salix cinerea* and *S.* x *rubens* accounted for 65% of the known distribution of all willows, occupying a total of 7,251 ha and 6,344 ha respectively. *S. babylonica* was the most common willow in Western Australia and Queensland, *S. nigra* in the Australian Capital Territory, *S. fragilis* in New South Wales and Tasmania and *S.* x *sepulcralis* in South Australia.

Table 3: Summary of willow distribution in Australia by State or Territory, including the total number of taxa recorded, the number of hectares infested and the number of Catchment Management Authority (CMA) or Natural Resource Management (NRM) regions where willows are known to occur.

	National	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
Willow taxa recorded (No.)	21	13	17	0	9	11	15	16	6
Area infested (ha*)	21015	161	3437	0	63	698	354	16055	246
Regions with willows (No.^)	38 (58^)	1 (1)	12 (13)	0 (1)	5 (14)	4 (8)	3 (3)	10 (10)	3 (6)

^Number in brackets is total number of CMA or NRM regions for that State or Territory

A present to potential distribution map was constructed for each taxon, but only a generic map showing the combined present to potential distribution of all assessed willows is presented here (Figure 3). These present to potential distribution maps can be used as decision making tools when determining which areas to monitor for future spread. Areas where willows are either limited in distribution or not known to occur, but are at high risk of invasion included:

- the New South Wales coastline,
- large areas of southern Queensland, southwest Western Australia and South Australia,

- southern Northern Territory, and
- far north west, south west and north east Tasmania.

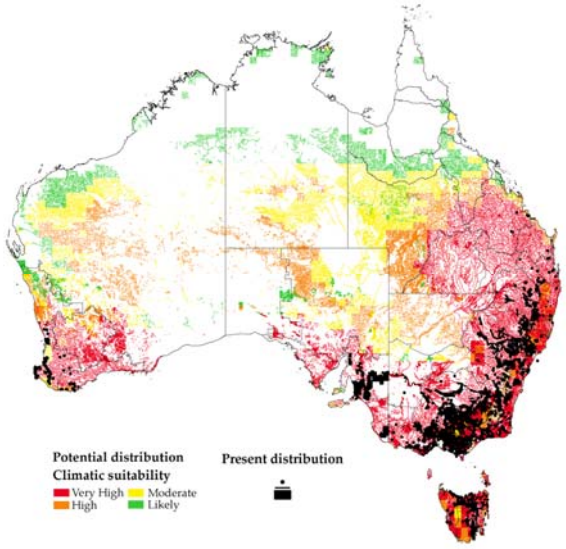

Figure 3: Present (black) and potential (other colours) distributions of willows (*Salix* spp.) in Australia. For potential distributions, red = very high climatic suitability, orange = high, yellow = moderate and green = likely.

Knowledge of willows distribution has significantly improved since 2006, when the process began (see Figure 4). For example, in 2006, there were very few records of willows in Victoria and only one record of willows lodged in the Western Australian Herbarium (a *Salix babylonica* weeping willow specimen). In contrast, in 2008, the Victorian distribution accounts for approximately three quarters of the total infestations mapped nationally and, in Western Australia, there are over 250 records of willows, with 6 taxa identified.

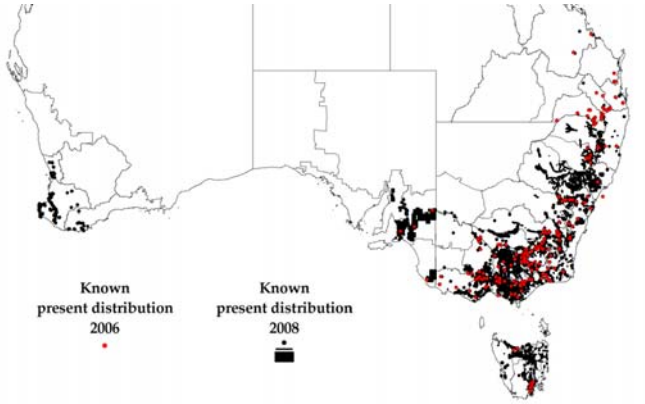

Figure 4: Known present distribution of willows across Australia in 2006 (red) and 2008 (black), showing an increase in knowledge of where willows occur since the inception of the National Willows Program.

When assessed for invasiveness and impact (see Table 4), the *Chamaetia* subgenus rated as low risk, whereas the other two subgenera rated as high risk.

Table 4: Assessment scores for the three subgenera, *Chamaetia* (alpine, arctic or mountain willows), *Salix* (tree or true willows) and *Vetrix* (shrub willows, sallows and osiers).

Subgenus	Invasiveness	Impacts	Invasiveness x Impacts	Rating	Confidence
Chamaetia	0.54	0.04	0.09	Low	0.36
Salix	0.67	0.87	0.57	High	0.69
Vetrix	0.84	0.79	0.55	High	0.71

Table 5 shows the overall ranking of the 32 remaining taxa at a national scale, including the scores given to each for the three main components and overall. As they are based on different criteria, the scores in Table 5 cannot be directly compared to generic assessments of other plants. However, these results can be extrapolated by comparing them in relation to the 16 willow taxa that have also been assessed using generic criteria as part of the Victorian noxious weeds review (DPI 2006).

Table 5: National ranking of willows based on total assessment score, including the reason they were assessed, the national invasiveness, impact and distribution scores given, the national prioritisation level given to each taxa and the level of confidence in the accuracy of each total score.

Note: 2 = Naturalised; 3 = Not known to be naturalised in Australia, but a) naturalised beyond their native range, b) exhibit invasive traits or c) are suspected of having low risk; 4a = Exempt from WoNS listing and weeds legislation in all States and Territories; 4b = Exempt from weeds legislation in Victoria; 5 No potential distribution in Australia;

National ranking	Scientific name	Reason for assessment	Invasiveness	Impact	Distribution	Total score (prioritisation level)	Confidence score
1	*S. triandra*	2	0.67	0.84	0.85	**0.83 (VH)**	0.63
2	*S. nigra*	2	0.8	0.85	0.71	**0.80 (H)**	0.58
3	*S. daphnoides*	3a	0.48	0.83	0.85	**0.79 (VH)**	0.47
4	*S. glauca*	3b	0.48	0.82	0.85	**0.79 (VH)**	0.33
5	*S. exigua*	3b	0.45	0.79	0.85	**0.77 (VH)**	0.53
6	*S. purpurea*	2	0.75	0.79	0.71	**0.76 (H)**	0.66
7	*S.* x *rubens*	2	0.7	0.87	0.57	**0.76 (H)**	0.65
8	*S. cinerea*	2	0.79	0.85	0.57	**0.75 (H)**	0.63
9	*S. viminalis*	2	0.66	0.79	0.71	**0.75 (H)**	0.68
10	*S. alba*	2	0.67	0.85	0.57	**0.74 (H)**	0.68
11	*S. babylonica*	2,4a	0.56	0.86	0.57	**0.73 (H)**	0.63
12	*S.* x *pendulina*	2	0.47	0.79	0.71	**0.72 (H)**	0.33
13	*S. x sepulcralis*	2	0.64	0.8	0.57	**0.71 (H)**	0.60
14	*S. fragilis*	2	0.48	0.82	0.57	**0.70 (H)**	0.67
15	*S. caprea*	4b	0.77	0.57	0.85	**0.68 (M(**	0.60
16	*S. alba* x *matsudana*	2, 4b	0.69	0.65	0.71	**0.67 (M)**	0.52
17	*S. gracilistyla*	3b	0.51	0.68	0.71	**0.67 (M)**	0.40
18	*S. pentandra*	3a	0.54	0.57	0.85	**0.66 (M)**	0.30
19	*S.* x *mollissima*	2	0.42	0.57	0.85	**0.64 (M)**	0.41
20	*S.* x *reichardtii*	2,4a	0.43	0.63	0.71	**0.63 (M)**	0.50
21	*S. eriocephala*	3a	0.48	0.52	0.85	**0.62 (M)**	0.53
22	*S.* x *sericans*	2	0.47	0.52	0.85	**0.62 (M)**	0.19
23	*S. myricoides*	2	0.56	0.49	0.85	**0.61 (M)**	0.39
24	*S.* x *calodendron*	2,4a	0.38	0.61	0.71	**0.61 (M)**	0.36
25	*S. aegyptiaca*	2	0.63	0.42	0.85	**0.58 (M)**	0.50
26	*S. elaeagnos*	3a	0.49	0.41	0.85	**0.56 (M)**	0.45
27	*S. myrsinifolia*	4b	0.56	0.38	0.85	**0.55 (M)**	0.26

28	*S. matsudana*	2, 4b	0.54	0.42	0.71	**0.53 (M)**	0.61
29	*S. chilensis* 'Fastigiata'	2	0.53	0.08	0.71	**0.33 (L)**	0.47
30	*S. integra* 'Hakuro-nishiki'	3c	0.39	0.02	0.85	**0.33 (L)**	0.41
31	*S. alba* var. *caerulea*	4b	0.47	0.02	0.71	**0.30 (L)**	0.49
32	*S.* x 'Boydii'	3c,5	0.37	0	0	**0.04 (L)**	0.42

Several taxa scored high or moderately high for all impacts questions, including the subgenus *Salix* and the following individual taxa: *S.* x *rubens*, *S. nigra*, *S. alba*, *S. fragilis*, *S.* x *sepulcralis* and *S. babylonica* (except that S. babylonica was given a medium score for Question 3 due to insufficient information).

General characteristics of willows with high intrinsic scores (i.e. combined invasiveness and impact scores) were: easily establish along waterways; may tolerate canopy cover; are fast-growing; can spread long distances by large quantities of seed; cause soil erosion; reduce water quality; impact on the structure of a range of habitats; facilitate the establishment of other invasive species; reduce the recreational value of waterways; and have little amenity value.

All of the taxa that received low invasiveness and impact scores and five taxa that received moderate scores had low confidence scores, meaning there was little information available to assess them. This lack of information may be an indication that these taxa do not have high impacts, as a lack of impact is unlikely to be recorded. However, further research is required before they can be considered truly low risk.

The level of awareness of the current and/or potential threat of willows in each region was determined by the management, training and awareness activities that have occurred (Figure 5). For example, control activities have been taking place in most regions of Victoria for a number of years, whereas land managers in south west Western Australia and south east Queensland have only recently become aware of the potential threat of willows in these States. By comparing the level of awareness within a region with the potential distribution of different taxa (Figure 5), we can identify where best to direct communications efforts.

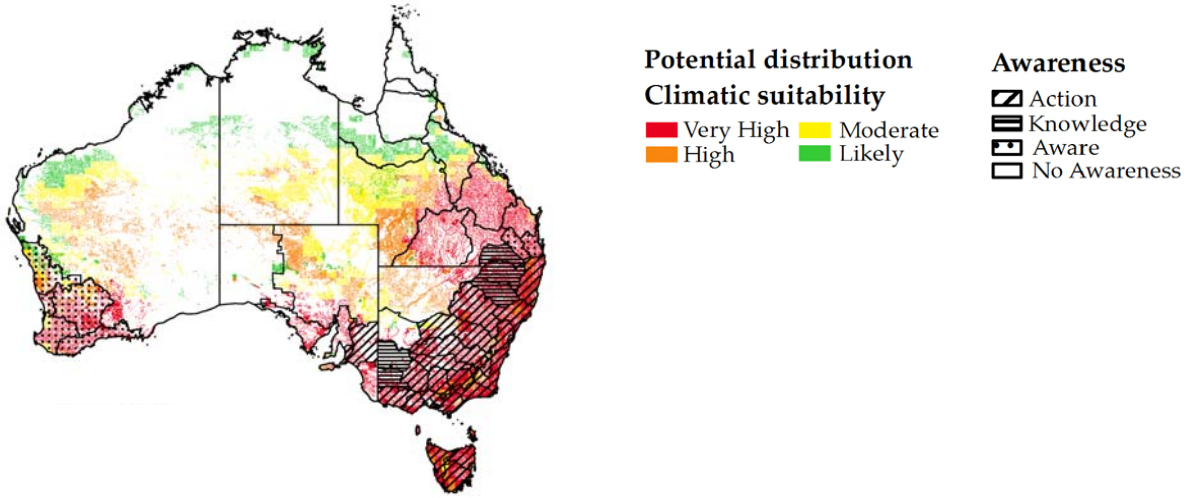

Figure 5: The potential distribution of willows across Australia and the level of awareness of the current and/or potential threat of willows in each region, as determined by management, training and awareness activities that have occurred. For potential distributions, red = very high climatic suitability, orange = high, yellow = moderate and green = likely. For level of awareness overlay, action = diagonal lines, knowledge = horizontal lines, aware = dots, no awareness = blank.

3.3 Assessing and improving management and control methods

3.3.1 National Willows Management Guide

The risk assessments provide a toolkit to assist in prioritising management actions at different scales. However, when managing willows, there are also numerous other considerations, including site-specific factors such as the sex, size, form and density of the willows, their location along a waterway, access to the site for people and machinery, adjacent vegetation and conditions downstream of the site.

A *National Willows Management Guide* (Holland Clift and Davies 2007) was developed to bring together detailed information about willows and their management to help people determine why, what, where, when and how willows should be managed. It includes information on the impacts and spread of willows, management and control options for various situations, as well as real life case studies highlighting how land managers have successfully managed willows.

As with the willows risk assessment, developing a *National Willows Management Guide* was a challenging task, given the diversity of views and situations in which willows are managed. On-ground managers with extensive experience in willow management from across Australia were brought together to debate best practice willow management and develop a set of agreed recommendations that could be included in the guide. To help ensure the manual provided the most relevant and up-to-date information possible, input was sought from over 100 people, including community groups, weeds officers, waterway managers, researchers and other people working on willows. It recognises that the control of all willows is not always necessary or desirable and that there is no one best method, but rather a range of factors that need to be considered and weighed up for each particular situation.

3.3.2 National Willows Research Forum

A National Willows Research Forum was held in February, 2007, in order to provide an opportunity for researchers and willow practitioners to:

- learn about past and current research on willows in Australia and the implications of this research for on-ground management of willows
- network with researchers working on willows across Australia
- contribute to the development of national research priorities for willows and
- identify opportunities for collaboration on research projects.

Invited speakers gave presentations on research conducted to date and an afternoon workshop session was then conducted to highlight the implications for management of this research and to develop future research and communications priorities. During each presentation, participants were asked to record any questions, implications for management and research gaps that they thought of. This enabled detailed information to be collected and collated and used as a prompt for participants during the question panels and afternoon workshop session.

The forum was attended by a diverse range of people, including on-ground managers, extension officers, policy officers, investors and researchers (Figure 6a). On their evaluation forms, all participants said that they found the research forum useful overall (Figure 6b). When asked what they found most useful about the forum, the most common responses were hearing an overview of willows research and activities, networking, prioritising research gaps and the format and running of the Forum.

a) b)

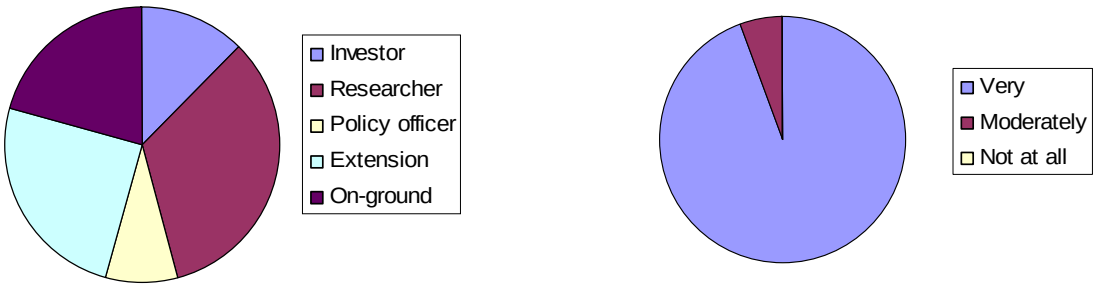

Figure 6: Research forum participants' responses to the questions a) 'how would you classify your role in relation to willows?' and b) 'how useful did you find the Research Forum overall?' (Holland 2007)

3.3.2.1 Research conducted to date

Topics covered by research to date include water usage, the willow sawfly, biological control, stream morphology, weed risk assessment, remote sensing, ecological impacts and dispersal dynamics. Outlines of some of this research can be found in the proceedings of the National Willows Research Forum (Holland Clift 2007).

Research to date has been conducted by numerous organisations and individuals across Australia. Research that has recently been completed includes:

- The development of catchment-scale mapping techniques (Noonan and Chafer 2007). These techniques can provide a powerful and cost-effective tool for prioritising control programs and monitoring results at a catchment scale.
- Understanding factors affecting the recruitment success of willows (Stokes and Cunningham 2006; Gehrig *et al*. 2006). Research by Stokes and Cunningham indicates that spread by vegetative means is most influenced by physical characteristics of the river, whereas the availability of mating partners is of greater importance in determining spread by seed. Gehrig et al. found that hybridisation between *Salix* taxa along the River Murray may provide a stimulus for increased invasiveness, as hybridisation can lead to new adaptive traits that are more compatible with colonised habitats.

Research currently underway includes:

- Tracking the extent and pattern of seed and pollen migration across the landscape using genetic markers, to help improve our ability to set priorities for management on a landscape scale.
- Use of decision models to assist in the efficient and effective control of *S. cinerea* (grey sallow). This research intends to determine the best management strategies for controlling grey sallow in alpine bogs in the Victorian Alps, with consideration of outside populations and management factors.
- Understanding the potential impact of the willow sawfly (*Nematus oligospilus*) in Australia. Research to date has focussed on understanding the current status of the sawfly in Australia and its potential impacts and spread (Finlay and Adair 2006; Ede 2006; Ede *et al*. 2007), with the next steps being focussed on how it can be effectively integrated into current willow management programs.
- Quantifying water savings from willow removal in south central New South Wales (Doody *et al*. 2006). Initial results indicate that there is a potential for water savings of 3-4 ML/ha if the willows situated in the stream bed with permanent access to water were to be removed.

4. Summary, recommendations and future work

This work has formed a basis for guiding and measuring progress towards the future management of willows across Australia. Such an evidence-based approach provides a more objective basis for future legislative decisions and management actions than has previously been possible for willows and, thereby, will hopefully enable conflicting views to be more effectively managed.

4.1 On ground management

Recommended management actions vary depending on factors such as whether or not the taxon has naturalised, its level of risk (i.e. combined invasiveness and impacts) and whether it can be feasibly eradicated.

Prevent establishment – non-naturalised, cultivated willow taxa

All four taxa that received a national prioritisation level of 'very high' (i.e. *S. triandra, S. daphnoides, S. glauca,* and *S. exigua*; see Table 5) are not yet known to have naturalised in Australia. There are no confirmed records of *S. triandra* and *S. daphnoides* in Australia, so management should focus on preventing their introduction. *S. glauca* and *S. exigua* have already been introduced, so management should focus on preventing their establishment. To achieve this, their removal from gardens and parks should be encouraged and a monitoring and incursions response program established, targeted to areas with suitable climates and habitats for these taxa. As people are unlikely to be familiar with these species, identification information should also be developed and disseminated to areas at high risk.

The potential distribution of *S. glauca* was confined to Tasmania, so efforts should focus on ensuring that it is not present in this state. *S. exigua* has a potential distribution in all States and Territories, but the area with highest climatic suitability was in northern New South Wales and southern Queensland.

Prevention should also be made a high priority for certain other taxa, where there are currently no confirmed records but the potential distribution is high. This includes:

- *S. babylonica, S. exigua* and *S. nigra* in the far south of the Northern Territory,
- *S.* x *sepulcralis*, *S. purpurea*, *S. cinerea and S. nigra in Queensland,*
- *S. purpurea*, *S. viminalis,* and *S.* x *pendulina* in South Australia,
- *S. nigra* and *S. viminalis* in Tasmania, and
- *S. viminalis* in Victoria.

Eradicate

All of the taxa given a 'high' national prioritisation level (*i.e. S. alba, S. babylonica, S. cinerea, S. fragilis, S. nigra, S. purpurea, S. viminalis, S. x pendulina, S. x rubens* and *S. x sepulcralis*) are known to be naturalised in Australia. Each of these taxa had the same potential for invasiveness and impact as those identified as 'very high' but, as they are already naturalised, their potential for further spread was less. Where feasible, these taxa should be targeted for eradication.

Based on current distribution knowledge, eradication is likely feasible for:

- *S.* x *rubens*, *S. alba*, *S.* x *pendulina* and *S. fragilis* in Queensland,
- *S.* x *rubens*, *S. nigra*, *S. cinerea*, *S. alba*, *S. babylonica*, *S.* x *sepulcralis* and *S. fragilis* in South Australia,
- *S. cinerea*, *S.* x *sepulcralis* and *S. babylonica* in Western Australia,

- *S. nigra, S. cinerea, S. alba, S. babylonica, S. purpurea, S.* x *sepulcralis, S. fragilis* and *S.* x *pendulina* in the Australian Capital Territory,
- *S. cinerea, S. babylonica* and *S. nigra* in certain regions and *S. viminalis*, *S. purpurea*, *S.* x *sepulcralis*, *S. alba*, and *S.* x *pendulina* across New South Wales,
- *S. cinerea*, *S. alba* and *S. purpurea* in Tasmania, and
- *S. purpurea, S.* x *pendulina* and *S. nigra* in certain regions of Victoria.

Manage the spread and protect key assets

Where eradication is not feasible in the near future, management should focus on preventing spread and protecting high value assets, such as Ramsar sites. The *National Willows Management Guide* (Holland Clift and Davies 2007) provides information needed to manage the spread and impacts of willows on different scales.

National recommendations include:

- Remove all male willows in Western Australia and Queensland to prevent them from pollinating nearby female willows and enabling their spread by seed. Less than 10% of plants surveyed in Western Australia were identified as male and the most common taxa in Queensland only occur as female plants.
- Monitor and protect Ramsar sites from invasion of nearby seeding willows found in townships of and streams around: Forrestdale and Thomsons Lakes, Peel-Yalgorup System, Muir-Byenup System, and Becher Point Wetlands in Western Australia.
- Monitor and protect other Ramsar sites from invasion of nearby seeding willows, if found. 'High' priority willows identified as being capable of spreading to Ramsar sites by seed include *S. alba*, *S. cinerea*, *S. nigra*, *S. purpurea*, *S. viminalis*, *S.* x *rubens* and *S.* x *sepulcralis*. In addition, *S. babylonica* and *S. fragilis* could potentially pose a threat to Ramsar sites by crossing with other taxa to form viable hybrids.

Raise awareness, educate and coordinate management

By comparing the level of awareness within a region with the potential distribution of different taxa (see Figure 5), we can identify where best to direct efforts in:

- awareness raising (e.g. areas with a high potential distribution with no awareness),
- training and dissemination of technical information (e.g. areas where people are aware of the willows threat, but not yet sure how to manage it), and
- cross-regional coordination and best practice management information (e.g. areas where active control is occurring and there is capacity to coordinate such efforts with neighbouring regions).

One of the major challenges in raising awareness of willows is creating simple messages that adequately educate people on what is a very complex issue. This can most easily be done by developing specific priorities relevant to regional or local areas and then focussing communications on these priorities.

A similar process was used during the willows risk assessment process, where efforts in training, awareness raising and mapping were tailored to specific regions and States. For example, awareness raising and on ground mapping efforts were targeted to Western Australia and Queensland, where there was very little knowledge or concern about the current or potential threat of willows. In contrast, training workshops and broad scale mapping techniques were targeted to other States, where willows were well established and, in many cases, being actively managed.

4.2 Legislation

The information derived from the willows risk assessments can be used to make sound, legislative decisions that focus on willows with the greatest or lowest risk. The assessments highlight certain changes that could be made.

4.2.1 Willows currently exempt from WoNS list

Of the three willow taxa currently exempt from the WoNS list, *S. babylonica* received a high invasiveness and impact score (ranking at number 11 out of 35 taxa assessed), and *S.* x *reichardtii* and *S.* x *calodendron* received moderate scores (ranking at number 20 and 23 respectively). At the regional scale, *S. babylonica* is ranked as one of the top ten highest risk willows in every CMA/NRM region except for the South Coast Region in Western Australia, where it is ranked at number twelve. By comparison, *S.* x *reichardtii* and *S.* x *calodendron* did not score higher than thirteenth ranking in any region, and ranked as low as 26 in certain regions.

It is therefore recommended that:

- *S. babylonica* be added to the WoNS list, and considered for declaration as noxious under state and local laws.
- Regional rankings and management priorities be used to declare *Salix* x *reichardtii* and *S.* x *calodendron* as noxious under state or local laws, where appropriate.

The exemption of *S. babylonica* (weeping willow) from the WoNS list appears to have implied that all weeping forms of willows are not invasive. For example, many regional workshop participants began the day thinking that only “weeping willows” occurred in their area and that these did not pose any problems. These participants were surprised to learn that not all weeping forms of willows are *S. babylonica*, but many instead are the self-fertile hybrid, *S.* x *sepulcralis*, which received a higher invasiveness score.

Although we attempted to conduct objective and transparent weed risk assessments through broad consultation, there will still be situations when the recommendations from these assessments are at odds with community sentiment. For example, although *S. babylonica* was ranked as a high risk willow, it is also often highly valued for its aesthetics. In areas where they currently do not adversely impact on the environment and the community wishes to retain them, management could focus on preventing their spread. Although capable, this species does not commonly spread by vegetative means. In addition, only female trees are present in Australia. Thus, for this species to spread, it generally requires compatible male plants of other taxa to be growing near enough for pollination to occur. Identifying and removing all compatible male plants within a few kilometres of this species would therefore greatly reduce the risk of it spreading to other areas where it may otherwise cause future impacts.

4.2.2 Willows currently listed as WoNS

The following willows were considered ‘low risk’ and could, therefore, be considered for removal from the WoNS list, as well as state or local legislation:

- *S. chilensis* ‘Fastigiata’ and *S. alba* var. *caerulea* from subgenus *Salix*;
- *S. integra* ‘Hakuro-nishiki,’ from subgenus *Vetrix*; and
- *S.* x ‘Boydii’ and many of the subgenus *Chamaetia (*except *S. glauca)*

For *S. integra* ‘Hakuro-nishiki,’ *S.* x ‘Boydii’, and the subgenus *Chamaetia* in particular, no information was found to answer almost half of the invasiveness questions. Further research on these taxa is therefore required before they can be considered truly low risk.

The main concern raised by nursery growers about legislation on willows was that the subgenus *Chamaetia* was declared as part of the entire *Salix* genus. Plants from this subgenus (commonly termed the 'alpine' or 'dwarf' willows) generally have fairly narrow climatic ranges and are quite different morphologically from the more commonly known shrub and tree forms. It appears that many taxa from the subgenus *Chamaetia* are low risk and therefore could be removed from the WoNS list. However, the assessments showed that we cannot generalise definitively based on subgenus. For example, *S. glauca* from subgenus *Chamaetia* was identified as one of the highest risk species at a national scale, whereas the subgenus as a whole was ranked as a low priority. Thus, prior to deeming any willows safe and removing them from current legislation, each taxon will need to be investigated to determine if it has become a weed elsewhere and if its biological traits and/or ecology suggest that it might be more invasive than is usual in members of that subgenus.

4.3 Future research priorities

One of the key outcomes of the *National Willows Research Forum* was the development of priority research gaps needing to be addressed for willows and project concepts for each of these gaps (Holland Clift 2007). The top 5 research themes identified and developed were:

1. Long term monitoring and evaluation of willow management in rehabilitation areas;
2. Further research on the water use of willows compared to other vegetation;
3. Study on community attitudes to willows and how to address them;
4. An analysis of the ecological impacts of willows, based on a synthesis of available pre and post willow removal monitoring data;
5. The biological management of willows.

As these priorities were developed and supported by a diverse range of participants, they provide a sound guide to where future investment should be made in willows research.

The *National Willows Risk Assessments* and *National Willows Management Guide* are both living documents that will need to be reviewed and adapted over time, as we gain better understanding and knowledge of where willows occur and how they affect the systems we work in. For example, to date, our understanding of the impacts and dispersal patterns of many taxa is still limited. In particular, taxa with low confidence scores should be made a priority for further research, focussing first on the five taxa that received moderate scores (i.e. *S. myricoides*, *S. myrsinifolia, S. pentandra, S.* x *calodendron* and *S.* x *sericans*), as they may pose a greater risk than their assessments currently indicate.

Although our understanding of where willows occur has been significantly increased, further mapping will generally still be required and site assessments conducted prior to commencing control activities. For example, where it is not desirable to remove all willows in an area, the sex of each willow will need to be identified and a decision made about whether to remove the male or female plants to prevent further spread by seed. Alternatively, if there is greater risk of spread by vegetative means, a decision could be made to remove sparse, streamside willows first. This decision should be based on a combination of the relative ranking or priority of each taxon within the region and site specific factors, such as the sex and location of willows and surrounding environmental influences. Information from the willow risk assessments and management guide will therefore need to be combined to determine the best outcome for each site.

4.4 National Willows Strategic Plan

Now that a strategic process has been developed and management, legislative, research and communications priorities have been identified, the future focus of the national program is to effectively implement these priorities.

At their meeting in October, 2007, the National Willows Taskforce conducted a detailed review of the National Willows Strategic Plan (ARMCANZ, ANZECC & FM 2001). To achieve the goals outlined in the Plan, the following key actions remain:

- All States to implement the recommendations made in the weed risk assessment report, including making relevant changes to legislation.
- Develop an inventory of all willow collections (including cricket bat plantations) and establish protocols for the appropriate management of these.
- Develop an ongoing, targeted training package for early detection and rapid response to new willow threats.
- Continue to implement and review the national willows communications strategy, including conducting management training workshops, improving the use of the national willows e-network and undertaking active engagement with the broader community in priority areas identified in the national weed risk assessment.
- Review and, if required, develop a submission to AQIS to effect changes in the national policy on importation of willows.
- Investigate options for the biological control of willows and continue research to understand the willow sawfly.
- Review and refine best practice guidelines and improve riparian rehabilitation practices.
- Continue to strengthen regional partnerships, particularly with public land managers.
- Document current alternatives to willows for various scenarios and conduct further research to develop additional alternatives.
- Develop project proposals for high priority research projects identified at the National Willows Research Forum and conduct an international willows conference to discuss shared issues and potential for collaboration on willows.
- Distribute available resource materials to all schools, TAFEs and universities.
- Review and update the National Willows Strategic Plan.

Given the extent of willow distribution across Australia and differences among jurisdictions, it is beyond the scope of the National Willows Program to set priorities at a finer scale. Instead, it has provided sound processes and the necessary tools to assist people in setting effective priorities at state and local levels. Such an evidence-based approach will help build credibility in future decision making and management activities at any level.

5. Conclusion

Since its establishment in 2005, the National Willows Taskforce has aimed to bring a balanced approach to management, by developing more objective, evidence-based processes combined with wide community discussion and feedback. This approach recognises the complex nature of willows and their management and has been successful in managing conflict, engaging a wide range of perspectives in constructive collaboration and developing critical willow management and control tools.

Key components of the program's success include:

- Starting from the premise that one cannot manage what one does not know. It was clearly recognised at the beginning that our understanding of the current and potential extent of willows in Australia was too limited for effective prioritisation.
- Engaging community and industry groups in constructive dialogue as a critical component of any decision making process.

- Coordination of efforts and sharing of research and management information across regions and States.
- The finding, as a result of the above, that willows (*Salix* spp.) are extremely complex and need to be considered as a diverse range of taxa, with different management priorities varying according to numerous broad scale and site specific factors.

Although there are still clearly gaps in our knowledge, the program now has a more solid basis for directing management and a clear benchmark by which it can measure future progress. Our focus is now shifting towards guiding the identification and implementation of on ground, legislative, communications and research priorities. These priorities are flexible and will be regularly reviewed and adapted, as new information becomes available.

The outcomes of the processes developed by the National Willows Program to date are not a prescription for action, but instead a tool kit to enable sound management decisions to be made at national, state, regional and local levels. These processes and the experience and principles behind them could be easily adapted and applied to other major environmental programs across Australia and internationally.

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