3.0 Willow management priorities across Australia

'Willows: friend or foe?'

3.1 Determining the extent of willows: Where are our willows?

Collating existing information

Surveys & Workshops

A comprehensive report (Wadley and Holland Clift 2007) was written on the results and outcomes from the workshops. Below is an excerpt from this report containing three key outcomes achieved. For further information on the workshops phase of this project and its implications for willow management please refer to the Willows workshop report.

On-ground mapping & ground truthing

All samples collected during the on-ground mapping phase were identified by an expert or at an herbarium, and all data collected was incorporated into the mapping database and weed risk assessments.

South Australia

Prior to this project, our understanding of willows distribution in South Australia was primarily confined to the River Murray. It was also thought that there were very few, if any, seeding willows found in South Australia. Thus, willows were not recognised as a great threat.

Following the workshop held at Renmark in November 2006, the SA Murray Darling NRM Board mapped all willows along their section of the River Murray in conjunction with a weed survey that had already been planned.

Through funding from the South Australian Government, a partnership was developed between Rural Solutions South Australia and the National Willows Program, which led to the engagement and collation of willow mapping information in regions not targeted through workshops.

Rural Solutions South Australia was contracted by the South Australian DWLBC to collate all South Australian willow mapping information. Their primary role was to assist in further updating the distribution data on willows in South Australia, by:

- liaising with people in regions where willows may exist that were not targeted through workshops,
- liaising with people from regions where workshops were held who did not attend a workshop, but have knowledge of where willows exist, and
- collating all maps and acetate sheets, and sending to the project team.

Eleven willow taxa have now been mapped in South Australia, these include:

- *S.* x *rubens*

- *S. nigra*
- *S. cinerea*
- *S. alba*
- *S. babylonica*
- *S.* x *sepulcralis*
- *S. fragilis*
- *S. alba* x *matsudana*
- *S. caprea*
- *S. matsudana*
- *S. chilensis* 'Fastigiata'

Mapping of seeding willows in the southern Fleurieu Peninsula

Rural Solutions South Australia mapped the distribution of seeding willows *S. cinerea* and *S. reichardtii* in the southern Fleurieu Peninsula from near Echunga to the south west limit of the peninsula in Autumn 2007. A follow up survey was carried out in during Spring 2007 to determine the gender of mapped plants whilst flowering.

The following summary of results is an excerpt from this report: *"S. cinerea* and *S. reichardtii* were recorded as being widely spread in watercourses and moist areas in the Mount Lofty Ranges and Fleurieu Peninsula of South Australia. Male and female plants of *S. cinerea* were most common in the Adelaide Hills east of Adelaide. Male plants of *S. reichardtii* were also common in the Adelaide Hills. Male plants of *S. cinerea* were only recorded in the Fleurieu Peninsula" (Coles & Willing 2007).

Queensland

Prior to visiting Queensland, there were 49 records of willows lodged in the Queensland Herbarium. As a result of the on-ground mapping phase of this project,

- 63 additional records of willows were mapped;
- seven willow samples were collected and identified by the Queensland Herbarium; and
- nine willow taxa are now confirmed to be present in Queensland:
  - *S.* x *rubens*
  - *S. nigra*
  - *S. cinerea*
  - *S. alba*
  - *S. babylonica*
  - *S. viminalis*
  - *S. fragilis*
  - *S.* x *pendulina*
  - *S. chilensis* 'Fastigiata'

Willows are known to occur primarily in southeast Queensland, from Brisbane to the New South Wales border and as far west as Goondiwindi, Stanthorpe and Warwick. Most observations in Queensland were made around towns and on rivers and creeks north of Warwick, to the border south of Stanthorpe. Many more willows were observed just south of the border in northern New South Wales, from Moree to Goondiwindi and east to areas around Tenterfield, Bonalbo, Casino and Lismore.

Previous records from the Queensland Herbarium of *S. cinerea* and *S. nigra* prior to this project were ground truthed by a project officer. *S. cinerea* was not found and samples taken from where *S. nigra* had been reported were identified by both the Queensland Herbarium and Ecology Australia and found to be the closely related *S. chilensis* 'Fastigiata'.

Western Australia

Prior to the on-ground mapping there was only one willow record lodged in the Western Australian Herbarium (a specimen of *S. babylonica* from the Perth area). As a result of the on-ground mapping phase of this project,

- twenty-nine willow samples were collected and lodged in the Western Australian Herbarium;
- six taxa and 250 records of willows were mapped; and
- less than 10% of plants were identified as male.

Willows are now known to occur across south west Western Australia, from Gin Gin in the north; to Albany, Augusta and Esperance in the south. Some of these willows were originally planted in townships, waterways and homesteads, but it is clear that willows have spread and are naturalising in streams and wetlands.

The greatest concern was the discovery of the grey sallow (*S. cinerea*) in two locations around Perth, at Bayswater and Armadale. Grey sallow has proven extremely invasive in Victoria's Alpine National Park, and New South Wales' Wingecarribee Swamp. In the right conditions grey sallow have been observed to explode from a few dozen plants to thousands of seedlings in just one season.

No willows were found in any of the Ramsar wetlands occurring within southwest Western Australia. However, there is the potential for willows to spread into, and impact upon, the following wetlands, as they are currently present in nearby streams and townships: Forrestdale and Thomsons Lakes, Peel-Yalgorup System, Muir-Byenup System, and Becher Point Wetlands. Such sites need to be monitored and kept protected from invasion by seeding willows.

The seven willow taxa now known to be present in Western Australia include:

- *S. cinerea*
- *S. babylonica*
- *S.* x *sepulcralis*
- *S.* x *reichardtii*
- *S.* x *sericans*
- *S. matsudana*
- *S. chilensis* 'Fastigiata'

Current distribution of willows

All of the data collated throughout the entire project was collated into a centralised database and interactive national maps were produced. These maps are scalable down to state, regional and local areas and also 'hot spots'. They include:

- National map showing the current distribution of all willow taxa
- National maps showing the current and potential distribution of each willow taxon

- State and Territory maps showing the current distribution of all willow taxa present

Where are our willows?

Twenty-one of the thirty-five willow taxa assessed during this project were recorded to occur across Australia. Willows infest a total of 21,015ha of waterways and riparian habitat and are found in all States and Territories except the Northern Territory (see Table 5a, see also Figure 6).

The thirty-eight NRM/CMA regions across Australia with willows can be seen in Table 5b. All seven taxa listed under "most common willow" rate as high priority taxa on a national scale (see "National and Regional Rankings" later in this report). They have high invasiveness and impact scores and moderate distribution scores that indicate that they have a high potential to spread in Australia, with serious consequences. They are second only in priority to taxa that are not established in Australia but have high invasiveness and impact scores, indicating that they have a high risk of serious consequences if they do establish in the wild.

The importance of preventing new incursions and eradicating weeds in early phases of establishment means that management priorities for individual regions will vary according to a taxa's distribution in each region. Each region's priority willows can be found in the Prioritisation Matrices accompanying this report. A national case study as an example for prioritising willow management using these matrices is provided.

Table 5a: Summary of willow distribution in Australia by State or Territory

	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*)	21,015	161	3,437	0	63	698	354	16,055	246
NRMs 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 NRM regions for that State or Territory
*see "**Potential for spread**" in this report for how this was calculated

Table 5b: Summary of willow distribution in Australia by NRM/CMA region

	NRM/CMA's with willows	Willows (ha*)	Most common willow		
			scientific name	common name	ha
ACT	ACT	161	*S. nigra*	black willow	92
NSW	Border Rivers/Gwydir	7	*S. babylonica*	weeping willow	4
	Central West	151	*S. fragilis*	crack willow	50
	Hawkesbury/ Nepean	57	*S.* x *pendulina*	Wisconsin weeping willow	11
	Hunter/Central Rivers	28	*S. babylonica*	weeping willow	10
	Lachlan	25	*S. babylonica*	weeping willow	9
	Lower Murray/Darling	1	*S. babylonica*	weeping willow	1
	Murray	748	*S. cinerea*	grey sallow	352
	Murrumbidgee	1,744	*S. fragilis*	crack willow	752
	Namoi	20	*S.* x *sepulcralis*	kemp willow (weeping willow)	8
	Northern Rivers	179	*S. nigra*	black willow	157
	Southern Rivers	460	*S.* x *rubens*	gold-crack willow	414

Section Three - Results

	NRM/CMA's with willows	Willows (ha*)	Most common willow		
			scientific name	common name	ha
	Sydney Metro	17	*S. cinerea*	grey sallow	10
NT	Nil	-	-	-	-
QLD	Border Rivers	27	*S. babylonica*	weeping willow	24
	Burnett Mary	4	*S. babylonica*	weeping willow	4
	Condamine	16	*S. babylonica*	weeping willow	15
	Fitzroy	5	*S. babylonica, S. nigra*	weeping willow, black willow	2, 2
	South East	11	*S. babylonica*	weeping willow	9
SA	Adelaide & Mount Lofty Ranges	43	*S.* x *rubens*	gold-crack willow (white crack willow, basket willow)	13
	Northern and Yorke	9	*S. fragilis*	crack willow	5
	SA Murray Darling Basin	642	*S.* x *sepulcralis*	Kemp willow (weeping willow)	486
	South East	4	*S. babylonica*	weeping willow	2
TAS	North	114	*S. fragilis*	crack willow	30
	North West (Cradle Coast)	130	*S. cinerea*	grey sallow	87
	South	109	*S. cinerea*	grey sallow	70
VIC	Corangamite	518	*S. alba*	white willow	242
	East Gippsland	2,808	*S. alba*	white willow	1958
	Glenelg Hopkins	44	*S. alba*	white willow	13
	Goulburn Broken	2,364	*S. cinerea*	grey sallow	993
	Mallee	3,253	*S. cinerea*	grey sallow	3252
	North Central	146	*S.* x *rubens*	gold-crack willow	63
	North East	1,323	*S. cinerea*	grey sallow	655
	Port Phillip and Westernport	4,364	*S. x rubens*	gold-crack willow	3919
	West Gippsland	1,231	*S. cinerea*	grey sallow	1181
	Wimmera	1	*S. babylonica*	weeping willow	1
WA	South Coast Region	50	*S. babylonica*	weeping willow	44
	South West Region	154	*S. babylonica*	weeping willow	123
	Swan	42	*S. babylonica*	weeping willow	33

*see "**Potential for spread**" in Section 3.2 of this report for how this was calculated

There are several NRM/CMA regions in Australia that have no records of naturalised willows, including:

- ***New South Wales:*** Western
- ***Northern Territory:*** Northern Territory
- ***Queensland:*** Burdekin, Cape York, Cape York - Northern Gulf, Desert Channels, Mackay , Whitsunday, Maranoa Balonne, Northern Gulf, South West, Southern Gulf, Torres Strait, Wet Tropics
- ***South Australia:*** Alinytjara Wilurara, Eyre Peninsula, Kangaroo Island, South Australian Arid Lands,
- ***Western Australia:*** Avon, Northern Agricultural Region, Rangelands

Although these regions currently have no recorded willows, there is potential for some willows to invade these areas (see the Current and Potential distribution maps accompanying this report). For this reason they each have a Prioritisation Matrix to highlight high priority taxa that have potential to spread to these areas. For the regions listed above, all willow taxa in the very high, high and medium priority lists should be able to be identified by land managers responsible for identifying new incursions, particularly where neighbouring regions have willows (see Current and Potential distribution maps accompanying this report).
A programme to remove these willow taxa from public and private gardens would also reduce the risk of willows establishing.

Which willows do we have?

Twenty-one of the thirty-five willow taxa assessed during this project were recorded to occur across Australia in varying amounts within each State or Territory (see Figure 6 and Table 6).

The taxon with the greatest distribution (see Figure 6 and Table 6) was *S. cinerea*, infesting a total of 7,251ha nationally. *S.* x *rubens* had the next greatest distribution infesting 6,344ha in Australia. These two willows account for 65% of the known national willow distribution, and both taxa occur in every state (except Northern Territory and *S.* x *rubens* was not recorded in Western Australia), although both taxa were recorded as only infesting 1ha each in Queensland. Additionally it is worth noting that *S.* x *rubens* is often difficult to differentiate from *S. fragilis,* therefore some records may be combined.

The following observations can be made:

- *S. babylonica* was the most common willow in both outlier states, ***Western Australia*** and ***Queensland***. Interestingly this is also one willow that is currently excluded from the WoNS listing and state noxious weed legislation, but perhaps should be given a more serious status.
- 60% of recorded willow infestations in the ***Australian Capital Territory*** are *S. nigra*, twelve other taxa contribute to the other 40% of mapped willows in that region.
- Willows mapped in ***Victoria*** account for approximately three quarters of the willow infestations mapped across Australia.
- Seventeen of the twenty-one taxa recorded nationally occur in ***New South Wales***, with *S. fragilis* accounting for one third of the total New South Wales extent of willows (1,181 of 3,437ha).
- *S. fragilis* was also the most common willow mapped in ***Tasmania***, which also had fifteen different willow taxa contributing to a total of 354ha of infestations.
- In ***South Australia***, *S.* x *sepulcralis* has the greatest distribution; it accounts for 70% of all willows mapped in South Australia, and 80% of this taxon's recorded infestation in Australia.
- Currently, there are no records of willows in the ***Northern Territory.***

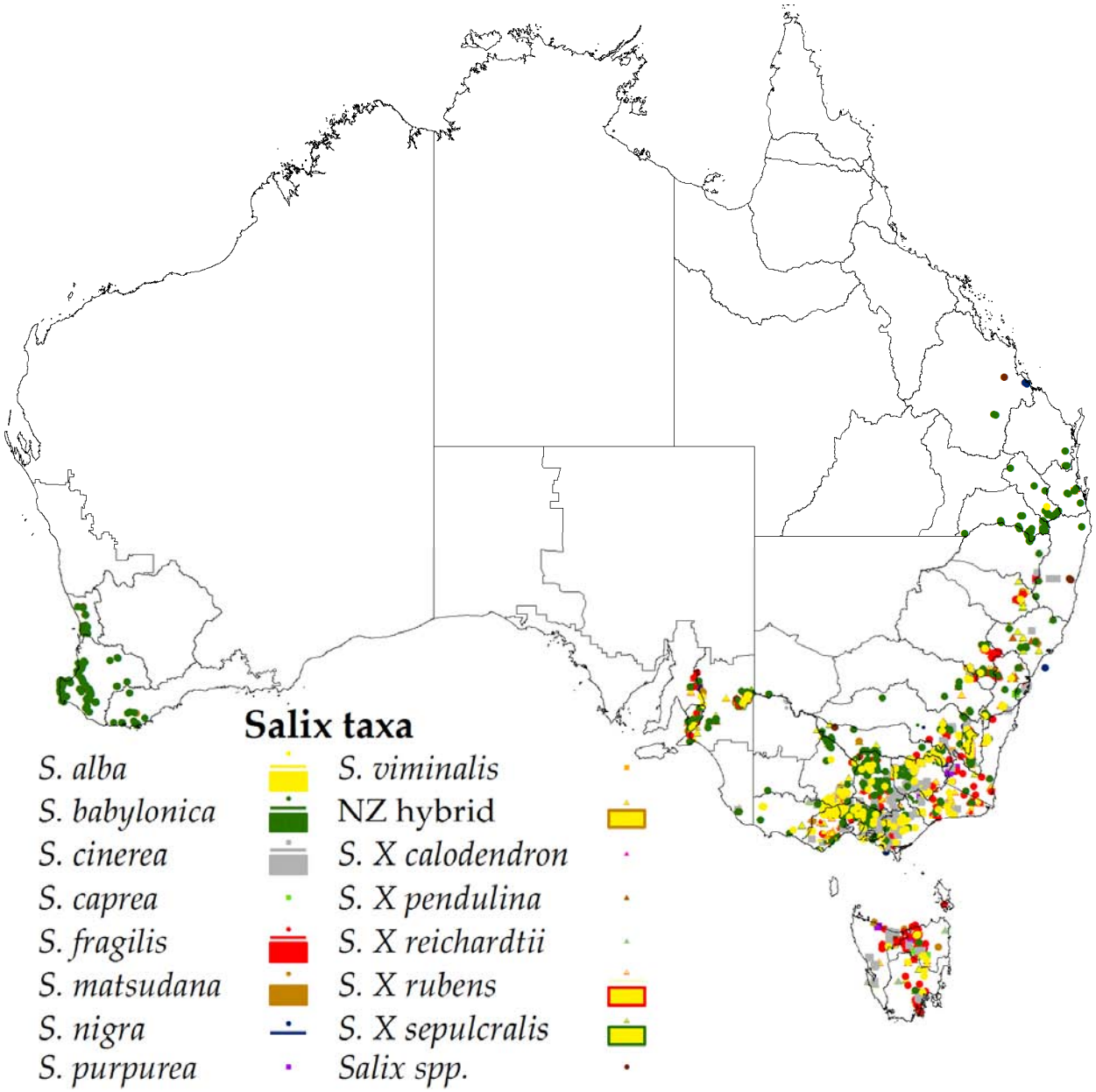

Figure 6: Current known extent of willow taxa in Australia

Table 6: Summary of willow distribution and infestations in Australia by taxa

Taxa	National (ha)	State or Territory (ha)						
		ACT	NSW	QLD	SA	TAS	VIC	WA
S. aegyptiaca	**0**	0	0	0	0	0	0	0
S. alba	**2,500**	11	116	1	18.5	16	2,338	0
S. alba var. *caerulea*	**6**	1	0	0	0	2	3	0
S. babylonica	**1,967**	15	258	54	79	2	1,359	200
S. caprea	**9**	0	4	0	1	3	1	0
S. cinerea	**7,251**	5	689	1	7	174	6,371	4
S. daphnoides	**0**	0	0	0	0	0	0	0
S. elaeagnos	**0**	0	0	0	0	0	0	0
S. eriocephala	**0**	0	0	0	0	0	0	0
S. exigua	**0**	0	0	0	0	0	0	0
S. fragilis	**1,495**	8	1,181	1	32	58	215	0
S. glauca	**0**	0	0	0	0	0	0	0
S. gracilistyla	**2**	0	0	0	0	2	0	0
S. chilensis 'Fastigiata'	**45**	0	4	1	5	1	8	26
S. integra 'Hakuro-nishiki'	**0**	0	0	0	0	0	0	0
S. matsudana	**87**	1	26	0	9	11	26	14
S. myricoides	**2**	2	0	0	0	0	0	0
S. myrsinifolia	**0**	0	0	0	0	0	0	0
S. nigra	**514**	92	280	2	1	0	139	0
S. pentandra	**0**	0	0	0	0	0	0	0
S. purpurea	**29**	1	13	0	0	5	10	0
S. triandra	**0**	0	0	0	0	0	0	0
S. viminalis	**11**	0	10	1	0	0	0	0
S. alba x *matsudana*	**41**	0	17	0	4	11	9	0
S. x 'Boydii'	**0**	0	0	0	0	0	0	0
S. x *calodendron*	**13**	0	13	0	0	0	0	0
S. x *mollissima*	**1**	0	0	0	0	0	1	0
S. x *pendulina*	**46**	5	17	1	0	13	10	0
S. x *reichardtii*	**162**	1	4	0	0	26	16	115
S. x *rubens*	**6,344**	15	753	1	50	9	5,516	0
S. x *sepulcralis*	**601**	4	50	0	491	21	34	1
S. x *sericans*	**1**	0	1	0	0	0	0	0

This is a summary of data from the Excel workbook accompanying this report "Willow distribution scores"

The willows with the smallest distribution, or no recorded distribution in most states, are commonly either amenity plants that are within gardens and not yet considered established in Australia (for example *S. integra* 'Hakuro nishiki'); or that occur most commonly in gardens but have few naturalised populations. Willows in the latter group include those that have low invasive ability, suggesting that they are unlikely to spread significantly, such as *S. chilensis* 'Fastigiata,' *S.* x *reichardtii,* or *S.* x *mollissima*; or those that have highly invasive traits and may be in an early phase of potentially large spread, such as *S. viminalis, S. caprea, S. nigra,* and *S. purpurea*.

However, this is not the case in states with small willow populations such as Queensland and Western Australia. The least common willows in these states are in fact willows that have spread and become large problems in other states (for example, *S. cinerea* in Victoria, *S. fragilis* in New South Wales and Tasmania, and *S.* x *sepulcralis* in South Australia). The ability of such willows to invade is reflected in their weed risk assessment results and their prominence in the priority matrices discussed later on. These taxa should be high priorities for monitoring and management (see "Willow Risk" in Section 3.2 of this report).

Several lesser-known willow taxa are likely to be present in larger numbers than the mapping data would suggest. This is due to their similarity to better-known taxa. For example, *S.* x *rubens* is similar to *S. fragilis.* It is likely that many of the willows recorded as *S. fragilis* are actually *S.* x *rubens.* Similarly, *S.* x *sepulcralis*, with a weeping habit, is very similar to the well-known weeping willow, *S. babylonica*. A perception that weeping willows are not invasive has probably lead to an under-reporting of both of these taxa, but many *S. babylonica* records are probably actually *S.* x *sepulcralis*. The willow identification part of the workshops focussed on differences between morphologically similar willow taxa.

All willow data collected during the course of this project can be viewed region by region in the GIS database accompanying this report (on a separate disk): "The current and potential distribution of willows (Salix spp.) in Australia."

All maps produced during the course of this project can be viewed in the layered PDFs accompanying this report, or in the GIS database.

Impact of updating willow distribution data

This project has played a major role in the creation and updating of regional maps containing willow distribution (Figure 7). The acquired knowledge on willow distribution from this project combined with weed risk assessment results will make a significant difference in the ability of regions and states to prioritise their willow management.

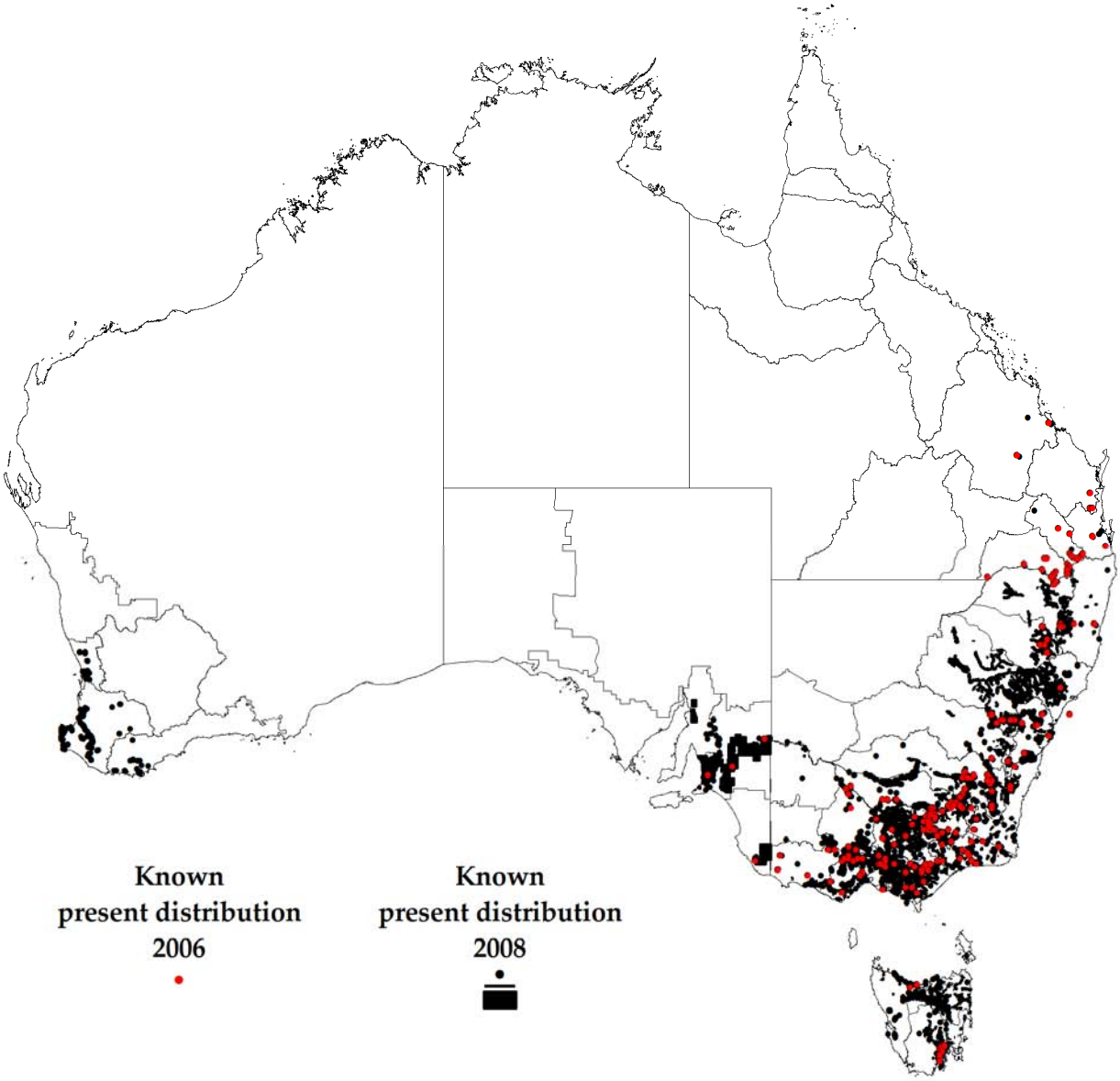

Figure 7: Comparison of known willow (*Salix* spp.) distribution before (2006), and after the project (2008).

Although the same process was used in every State/Territory, the mapping data collected varied among different regions. The workshops component made huge progress to vastly improve current knowledge of willow distribution. The workshops have highlighted the lack of data prior to this project, and generated much enthusiasm towards willow mapping across the regions, which is continuing today.

A summary of data in each state is listed below, for more detail see Wadley and Holland Clift (2007).

Australian Capital Territory

The ACT already had a large amount of willow distribution information prior to the project. The mapping session in the workshop helped to fill gaps and also added further detail to enhance existing knowledge.

The NWT formed a sound partnership with the Upper Murray Catchment Coordinating Committee (UMCCC), who undertook intensive mapping and ran additional workshops. This enhanced the current knowledge of willow distribution massively.

New South Wales

Willow distribution information in NSW was extremely variable prior to the project. The southern and central areas of NSW (e.g. Murrumbidgee & Lachlan regions) had reasonable records of willow information, and the project updated this and filled gaps. The northern regions (e.g. Namoi and Border Rivers Gwydir) had considerably less, or no, willow mapping records, therefore the project has played a major role in creating knowledge of willow distribution for these regions.

Mapping of willows in the Namoi region highlighted some major gaps in current knowledge of willow distribution, as there were previously thought to be no willows in this region.

South Australia

Prior to the project it was thought that willows were not a bug threat as they were mostly confined to the River Murray, and there were very few, if any, seeding willows.

Mapping of all willows along the Murray Darling NRM Board's section of the River Murray occurred and additional workshops (supported by South Australian Government, Rural Solutions and the National Willows Program) added further data to willow distribution knowledge. This also led to the discovery of *S. cinerea* (grey sallow), a potential large threat to the River Murray's catchment.

Tasmania

The Strategic Planning for Willow Management in Tasmania project conducted in 2003, and the current Tasmanian Seeding Willow Eradication project has led to a large amount of willow mapping information being collected for the state. This data was collated prior to the workshop series, and the workshops were used to add value to this data, and add data for areas where data did not exist.

Victoria

Prior to the project there had been limited mapping of willows in Victoria. The workshop series in Victoria has updated current distribution data significantly, and been able to challenge waterway managers to realise the importance of identifying and mapping key willow taxa in their region when determining priorities for management, in order to help prevent further spread, as well as reduce existing impacts.

Western Australia and Queensland

Queensland and Western Australia were not a part of the workshops series, and previously had very few records of willows. Regions in both these states were chosen

for strategic on-ground mapping conducted by a willows project officer. This improved mapping and awareness of the potential willow problem in both states. Until this project mapped willows in south west Western Australia, there was only one confirmed willow record. There are now 250 confirmed records of six different willow taxa, occurring throughout Western Australia. Awareness of willows in Western Australia and their impacts has begun, including print and radio media.

3.2 Weed risk assessment: Which are our worst willows?

Willow invasiveness & impacts

As described in the method section, the invasiveness criteria from the Victorian Weed Risk Assessment were used to successfully differentiate between the willows assessed in this project. The invasiveness scores are presented in Table 9 and are discussed further below.

Compared to willow impacts scores from the Victorian Weed Risk Assessment (in Figure 3), the impacts questions for the Willows Risk Assessment resulted in a greater spread of scores across all the criteria (Figure 8). The impact scores are presented in Table 9.

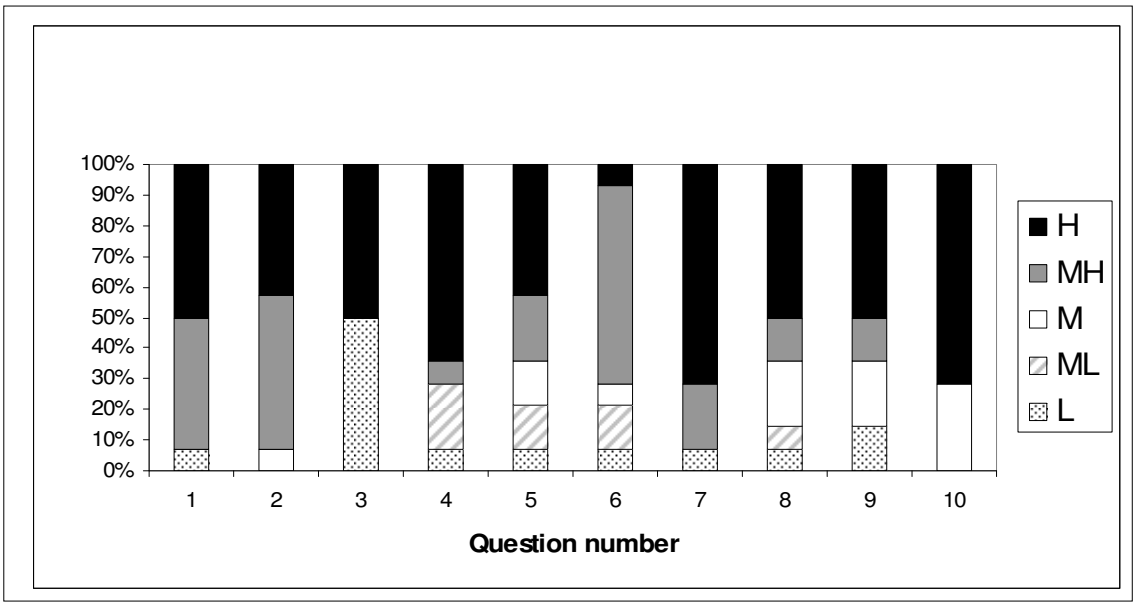

Figure 8: Spread of scores from the willow impacts risk assessment. Proportion of willows that scored H, MH, M, ML, or L for each question.

Willow distribution

Potential for spread

The potential for spread was determined by considering the current distribution of each willow, and comparing it with its potential distribution. Current distributions were

calculated from the mapping data that was sourced prior to, and during, the willow workshops.

The current distribution was measured by converting the data from the mapping project into hectares, by:

- calculating the areas of the polygon data;
- converting each point datum to 1 hectare; and
- measuring the length of the line data and multiplying each line by 20m (it was assumed that willows could colonise approximately 10m of riparian vegetation on either side of a waterway).

These present distribution areas were calculated for each willow taxon at a national scale, and also within each NRM/CMA region across Australia.

Potential distributions for each willow taxon were determined using a climate analysis that was then constricted to suitable habitat types. Using *CLIMATE* (Pheloung 1986) software, current distribution data from each taxon's native and invaded range was analysed to determine suitable climates within Australia for naturalisation to occur. This data was sourced online: the Global Biodiversity Information Facility (GBIF) and the Australian Virtual Herbarium (AVH); from the willow mapping project; and from literature such as Floras.

Suitable habitats for each willow taxon were determined from the literature, and *ArcGIS 9* software was used to refine the raw climate match to suitable habitat types according to the National Vegetation Information System (DEWR 2007), listed in Appendix 4. See Appendix 5 for the list of habitat types used to model each taxon. The potential distribution of each willow taxon was calculated at a national scale (for example, see Figure 9 for the potential distribution of *S. babylonica* at a national scale) and for each NRM/CMA region across Australia. The potential distributions of each willow taxon at the national and state/regional levels are presented in the layered PDFs associated with this report.

Present vs potential distribution

"The ratio of present to potential distribution provides an indication as to the stage that spread of a weed has reached. Another way of expressing this is the relative position of the taxa on its invasion graph [Figure 10]. Weeds that have reached, or nearly reached, the full limit of their distribution are not a major concern in terms of potential spread and impacts. However weeds currently occupying a small area of their potential range, which are in the 'lag' or 'sleeper' phase, should become a management priority. An important outcome of comparing present to potential distribution is the ability to target early intervention actions against weed invasions more effectively. Early intervention not only achieves better results from government and land manager investment, but also reduces costs of control and impact on social, environmental and economic values" (DPI 2006).

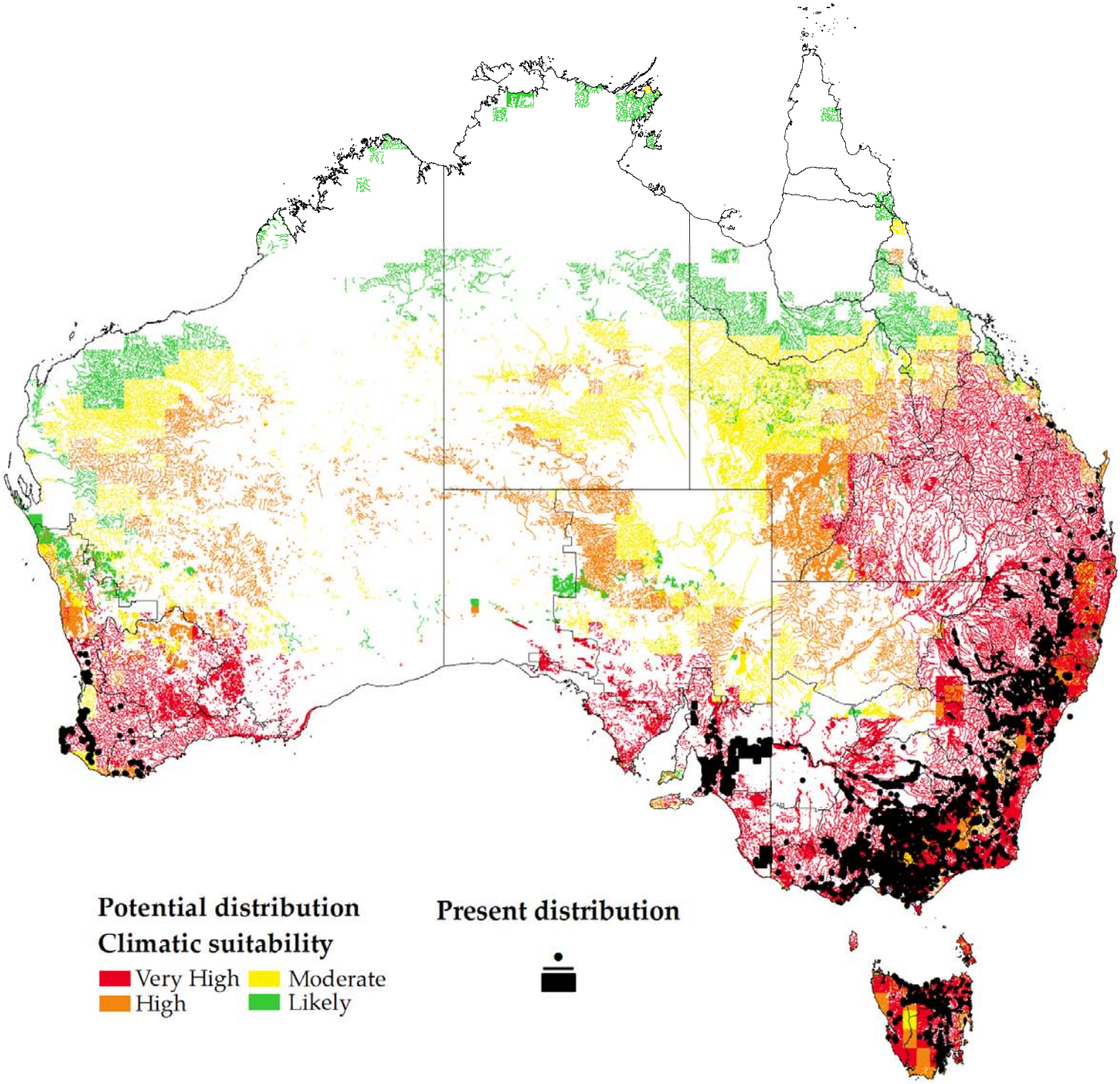

Figure 9: Present vs potential distribution of willows (*Salix* spp.) in Australia

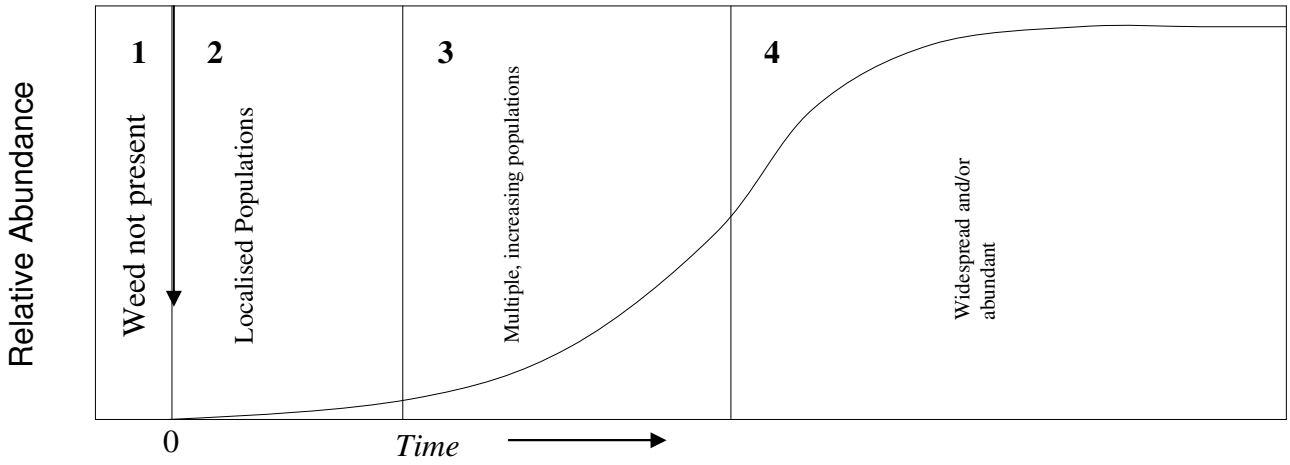

Figure 10; Invasion graph indicating stages of expansion of a new species into a habitat. (Adapted from Groves (1992) and Hobbs (1991)).

Using the ratios listed in Table 7 (below), a distribution score was allocated to each willow taxon at a national level and within each NRM/CMA across Australia. The distribution scores at the national level are presented in Table 9. For the distribution scores at the NRM/CMA level, see the Excel workbook, Willow Distribution Scores, associated with this report.

Table 7: Intensity ratings for evaluating the present compared to potential distribution of a weed.

Rating	Distri-bution Score	Pres:Pot Ratio	Statewide Descriptive	Regional or CMA Descriptive Rating
Very High	1.00		Infestation(s) that is able to be eradicated with no chance of reinvasion from outside of area of control (interstate).	Infestation(s) that is able to be eradicated with no chance of reinvasion from outside of area of control (interstate/ other region, etc.).
High	0.85	> 100,000	Infestation(s) that is able to be eradicated with some chance of reinvasion, less than 1,000ha in Vic.	Infestation(s) that is able to be eradicated with some chance of reinvasion.
Medium High	0.71	> 1:10,000	Several, **OR** widely scattered small, infestations, **OR** one large infestation.	Several small infestations beyond eradication.
Medium	0.57	1:100 - 1:10,000	Several large infestations **OR** lots of multiple widely scattered infestations **OR** a few combinations of both.	A large partially dispersed infestation **OR** few widely scattered small infestations.
Medium Low	0.42	1:10 - 1:100	Multiple large infestations **AND** multiple small infestations.	Numerous large dispersed infestations **OR** lots of scattered small infestations.
Low	0.28	1:2 - 1:10	The majority of region infested with some large areas still “clean” (more “clean” areas than infested).	The majority of region infested with some large areas still “clean” (more “clean” areas than infested).
Very Low	0.14	< 1:2	The majority of region infested with some smallish areas still “clean” (less “clean” areas than infested).	The majority of region infested with some smallish areas still “clean” (less “clean” areas than infested).
Extremely Low	0	1:1	Reached full potential – but may increase in density within infested area **OR** no suitable climate match in the state.	Reached full potential – but may increase in density within infested area **OR** no suitable climate match within the CMA/NRM.

Present vs potential distribution map

By comparing the current and potential distribution of willows (Figure 9) we can see not only how much further willows can spread, but also use this information as a decision making tool when determining which areas to monitor for willow spread.

For more detailed information on the current and potential distribution of different willow taxa across Australia, or for a detailed map of the current distribution of all the willow taxa in your state or region, see the layered PDFs of the National and State maps accompanying this report.

- Much of the ***Australian Capital Territory*** is very highly suitable for willow establishment, and a proportion of this extent appears to have been reached. Management therefore needs to be a coordinated effort between affected regions in New South Wales.
- Large areas along the ***New South Wales*** coast currently has no willow records, although it is has very highly suitable climate and habitat for willows to establish. Combined with willow infestations surrounding these coastal areas, these areas are at a high risk of willow invasion.
- There are large areas of southern ***Queensland*** where willows have high potential to establish. Only a small proportion of this is already invaded, therefore management needs to focus heavily on eradication and preventing spread.
- Although there are no records of willows in the ***Northern Territory***, there is some potential for willows to establish here. Climate and habitat here is highly suitable in the far south, and reduces to moderate or likely in central areas and the far north.
- ***South Australia*** has determined the extent of its willow infestations as a result of this project and these are centred around, Northern and Yorke, South Australian Murray Darling Basin, South East and Eyre Peninsula all have very highly suitable for willow establishment and all these regions, aside from Eyre Peninsula region, have willows.
- In ***Tasmania*** the far north west and far south west are currently recorded to be willow free. Due to very high suitability for willow establishment in these areas, and the presence of willows nearby, these areas are at high risk of willow invasion. This is also true for the north east of Tasmania.
- Much of ***Victoria*** (like the Australian Capital Territory) is very highly suitable for willow establishment, and a large proportion of this extent appears to have been reached. Management therefore needs to be a coordinated effort between affected regions, in both Victoria and leading into New South Wales and South Australia.
- ***Western Australia*** is in a similar situation to Queensland with large areas of suitability for willow establishment, and only a small proportion of this area currently recorded with invasions. Outside of the south western NRM regions, there is much lower risk of willows establishing.

Willow risk

The weighted invasiveness and impact scores for each willow taxon were added together (invasiveness x 0.12 + impact x 0.56), and this intrinsic score (based on the biological and ecological characteristics of each willow taxon) was used to rank the willows from highest risk to lowest risk (as in Table 8).

Table 8. Willows ranked according to weighted impact and invasiveness scores

Scientific name	Common name	Score*	Group	Conf.
S. x *rubens*	gold-crack willow	0.57	HIGH	0.65
S. nigra	black willow	0.57		0.58
S. cinerea	grey sallow	0.57		0.63
S. subg. *Salix*	tree willows, true willows	0.57		0.69
S. alba	white willow	0.55		0.68
S. triandra	almond willow	0.55		0.63
S. babylonica	weeping willow	0.55		0.63
S. subg. *Vetrix*	shrub willows, sallows and osiers	0.55		0.71
S. purpurea	purple osier	0.53		0.66
S. x *sepulcralis*	Kemp willow (weeping willow)	0.53		0.60
S. daphnoides	violet willow	0.52		0.47
S. viminalis	common osier	0.52		0.68
S. fragilis	crack willow	0.52		0.67
S. glauca	Arctic grey willow	0.52		0.33
S. exigua	sandbar willow	0.50		0.53
S. x *pendulina*	Wisconsin weeping willow	0.50		0.33
S. alba x *matsudana*	New Zealand hybrid willow	0.44	MEDIUM	0.52
S. gracilistyla		0.44		0.40
S. caprea	goat willow (pussy willow)	0.41		0.60
S. x *reichardtii*	pussy willow	0.40		0.50
S. x *calodendron.*	pussy willow	0.39		0.36
S. pentandra	bay willow	0.38		0.30
S. x *mollissima*		0.37		0.41
S. x *sericans*	pussy willow	0.35		0.19
S. eriocephala		0.35		0.53
S. myricoides	bay willow	0.34		0.39
S. aegyptiaca	Egyptian willow	0.31		0.50
S. matsudana	tortured willow	0.30		0.61
S. elaeagnos	hoary willow (bitter willow)	0.29		0.45
S. myrsinifolia	dark-leaved willow	0.28		0.26
S. chilensis 'Fastigiata'	Chilean pencil willow	0.11	LOW	0.47
S. subg. *Chamaetia*	alpine, arctic or mountain willows	0.09		0.36
S. alba var. *caerulea*	cricket bat willow	0.07		0.49
S. integra 'Hakuro-nishiki'	Nishiki willow	0.06		0.41
S. x *'Boydii'*	Boyd's willow	0.04		0.42

*Scores were calculated by adding the weighted invasiveness and impact scores together. See the Excel workbook, Willow scores, accompanying this report for more details.

A distribution graph of these scores showed that they fell into three main groups, with high, medium and low scores (Figure 11).

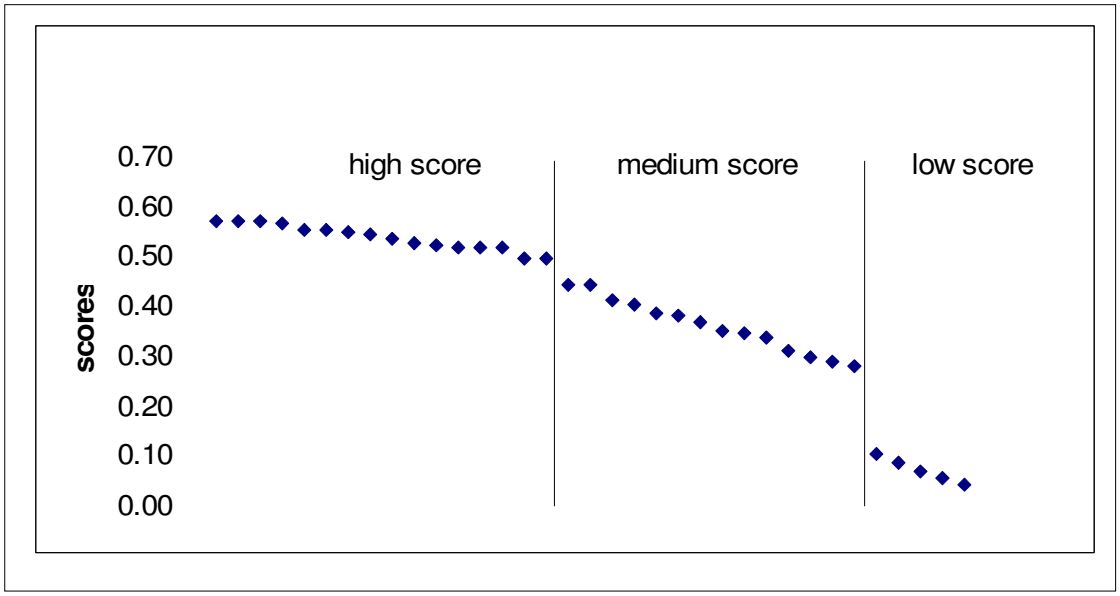

Figure 11: Willow distribution scores

These groups were used with the distribution scores for each willow to create a national prioritisation matrix, and a regional prioritisation matrix for each NRM/CMA across Australia. The combined impact and invasiveness scores determined which column a willow appeared in: high medium or low; as indicated in Table 8. The distribution scores determined which row a willow would appear in: 0.85 (high), 0.71 or 0.57 (medium), 0.42 or 0.28 or 0.14 (low). These categories were chosen to indicate the feasibility of control, based on the current and potential distribution of each taxon.

Prioritisation matrix – an explanation

The *colours of the cells* in the prioritisation matrix represent the importance of managing each willow taxon in the region. A summary of the colours, their relative priority and a rationale for prioritisation is in Figure 12.

The prioritisation matrix that resulted from using data on a national scale is in Figures 13 a & b. By reading across the columns from left to right, you can see at a glance which willows have the worst potential for invasiveness and impacts, which have a moderate potential, and which are a low risk. Similarly, down the rows, from top to bottom you can see which willows have the highest potential distribution, and which have the lowest.

Those with the highest potential distribution (in the first row) are considered suited to the climate of the region and able to establish, but also able to be eradicated. Those in the second row may be beyond eradication, but, by comparison with the last row, still have a long way to spread and would be worth investing in management to prevent their spread.

The bottom row contains willows that have either spread to occupy a large part of their potential range, or are unlikely to establish in the region due to unsuitable climate. In both cases the willow taxon will be a low priority for management; because it poses a low risk to the region, because it is unlikely to establish, or because it has spread so far that it would take a large amount of resources to manage it. In the latter case, management of these willows may occur as part of a site-led approach to protect valuable assets in the region.

<table>
<tr><th></th><th colspan="3">Invasiveness and Impact score</th></tr>
<tr><th>Distribution score</th><th>H</th><th>M</th><th>L</th></tr>
<tr><td>H</td><td>VERY HIGH PRIORITY
High invasiveness and impact risk. Either not yet naturalised in the region, OR likely to be able to be eradicated.</td><td rowspan="2">MODERATE PRIORITY
Medium invasiveness and impact risk. Either a high potential for spread in the region, OR able to be eradicated.</td><td rowspan="3">LOW PRIORITY
Considered a low priority for management because they have a low potential for invasiveness and impacts, and either have already spread across a large part of their potential range, OR are unlikely to establish in the region due to unsuitable climate.</td></tr>
<tr><td>M</td><td>HIGH PRIORITY
High invasiveness and impact risk. High potential for spread in the region.</td></tr>
<tr><td>L</td><td colspan="2">LOW PRIORITY
Considered a low priority for management because they have already spread across a large part of their potential range, OR unlikely to establish in the region due to unsuitable climate.</td></tr>
</table>

Figure 12: Explanation of the prioritisation matrix

Management options for each of the prioritisation categories

Very High Priority

Very High priority willows should be managed by either Alert or Eradicate management strategies. A description of these strategies and a method to decide which one to use is below:

- For willow taxa not yet naturalised in the region (marked with an *)
  - *Alert programmes* should be established in the areas that are climatically suited to these taxa (as indicated by the potential distribution maps). Land managers must be able to identify the willow taxa that are at risk of

establishing in their region. A response plan for eradication in the event of an incursion must also be prepared in advance.

  - A programme to encourage the removal of these taxa from public and private gardens and land will reduce the risk of these taxa establishing.

- For willow taxa naturalised in the region
  - An assessmnet should be made of the feasibility of eradicating these willow taxa from the region.

High priority

- These willow taxa are likely to be beyond eradication in the immediate future. However, there may be small outlier populations that can be removed to prevent the infestations from becoming worse and from spreading to new areas.
- Large infestations that are beyond eradication in the short-term should be managed to reduce their impacts on waterways, and to minimise their risk of spread. See the willow management guide (Holland Clift & Davies 2007) for more information.

Moderate priority

- For willow taxa not yet naturalised in the region (marked with an *)
  - Monitoring programmes should be established in the areas that are climatically suited to these taxa (as indicated by the potential distribution maps). Land managers must be able to identify the willow taxa that are at risk of establishing in their region.
  - A programme to encourage the removal of these taxa from public and private gardens and land will reduce the risk of these taxa establishing. However, as these willow taxa do not pose as high a risk as Very High priority taxa, they may be less of a focus than higher priority taxa.
- For willow taxa naturalised in the region
  - An assessmnet should be made of the feasibility of eradicating these willow taxa from the region. Again, their lower risk makes them a lower priority for eradication, and may occur after higher priority taxa have been eradicated or controlled.
- Large infestations that are beyond eradication in the short-term may be managed to reduce their impacts on waterways and to minimise their risk of spread. However, they pose a smaller risk than higher priority taxa and their control may be delayed until higher priority taxa have been managed. See the willow management guide (Holland Clift & Davies 2007) for more information on management techniques.

Low Priority

- For low priority taxa that are very widespread, but have high or moderately high impact scores

  - Where these willows impact on waterways they should be managed to reduce their impacts. See the willow management guide (Holland Clift & Davies 2007) for more information on management techniques.

- Low priority taxa that have no potential distribution in the region (indicated by a ^)
  - These willows are unlikely to establish and/or spread far in the region and may be suitable for use in public and private gardens. However, if any of these willow taxa are capable of setting seed, they should not be grown within 100km of susceptible climatic regions. They may also be capable of pollinating other willow taxa within at least a 1km radius. See the willow management guide (Holland Clift & Davies 2007) for more information on cross-pollination.
- Low priority taxa that have low invasivenss and impact scores
  - The climate in the region may be suited to the establishment of these willow taxa, but their impacts and invasiveness is so low that they pose a much lower risk to waterways than other taxa. They could be removed as the lowest priority in a region, unless they are capable of fertilising other willow taxa within pollinating distance. See the willow management guide (Holland Clift & Davies 2007) for more information on cross-pollination.

National prioritisation matrix

The national prioritisation matrix for willow taxa is presented in Figures 13a & b. A discussion of the use of this matrix for setting national priorities for willow management is presented in the next section of this report, "The national perspective as a case study for regional prioritisation."

	Invasiveness and Impact score		
Distribution score	**H**	**M**	**L**
H	*S. triandra** *S. daphnoides** *S. glauca** *S. exigua**	*S. caprea* *S. pentandra** *S.* x *mollissima* *S. eriocephala** *S. myricoides* *S. aegyptiaca** *S. elaeagnos** *S. myrsinifolia**	*S. integra 'Hakuro-nishiki'**
M	*S.* x *rubens* *S. nigra* *S. cinerea* *S. alba* *S. babylonica* *S. purpurea* *S.* x *sepulcralis* *S. viminalis* *S. fragilis* *S.* x *pendulina*	*S. alba* x *matsudana* *S. gracilistyla** *S.* x *reichardtii* *S.* x *calodendron* *S.* x *sericans* *S. matsudana*	*S. chilensis 'Fastigiata'* *S. alba* var. *caerulea*
L			*S.* x *'Boydii'^*

Figure 13a: Prioritisation matrix at a national scale - Scientific names
* Not known to be naturalised in Australia ^ No potential distribution in Australia

Distribution score	Invasiveness and Impact score		
	H	**M**	**L**
H	almond willow* violet willow* Arctic grey willow* sandbar willow*	goat willow (pussy willow) bay willow* S. x mollisima S. eriocephala* bayberry willow Egyptian willow* hoary willow (bitter willow)* dark-leaved willow*	Nishiki willow*
M	gold-crack willow black willow grey sallow white willow weeping willow purple osier weeping willow (kemp willow) common osier crack willow Wisconsin weeping willow	New Zealand hybrid willow S. gracilistyla* pussy willow (x reichardtii) pussy willow (x calodendron) pussy willow (x sericans) tortured willow	Chilean pencil willow Cricket bat willow
L			Boyd's willow^

Figure 13b: Prioritisation matrix at a national scale - Common names

* Not known to be naturalised in Australia ^ No potential distribution in Australia

National and regional rankings of the willow taxa

The relative importance of each of the three components of the assessment was determined using an analytical hierarchy process. Consequently, the overall weighting for the three components of the willow risk assessment were: invasiveness (12%), impacts (56%) and distribution (32%). These are the weightings that appear in the calculation below.

The weighted invasiveness and impact scores for each willow taxon were added to the weighted distribution scores for each willow taxon in each NRM/CMA region across Australia according to the following function:

> Weighted invasiveness score x 0.12 + weighted impact score x 0.56 + distribution score x 0.32.

The national ranking that resulted from this calculation is in Table 9.

Table 9. National ranking of willows based on total assessment score

Willow	Invasiveness	Impact	Distribution	Total Score
S. triandra	0.67	0.84	0.85	**0.83**
S. nigra	0.80	0.85	0.71	**0.80**
S. daphnoides	0.48	0.83	0.85	**0.79**
S. glauca	0.48	0.82	0.85	**0.79**
S. exigua	0.45	0.79	0.85	**0.77**
S. purpurea	0.75	0.79	0.71	**0.76**
S. x *rubens*	0.70	0.87	0.57	**0.76**
S. cinerea	0.79	0.85	0.57	**0.75**
S. viminalis	0.66	0.79	0.71	**0.75**
S. alba	0.67	0.85	0.57	**0.74**
S. babylonica	0.56	0.86	0.57	**0.73**
S. x *pendulina*	0.47	0.79	0.71	**0.72**
S. x sepulcralis	0.64	0.80	0.57	**0.71**
S. fragilis	0.48	0.82	0.57	**0.70**
S. caprea	0.77	0.57	0.85	**0.68**
S. alba x *matsudana*	0.69	0.65	0.71	**0.67**
S. gracilistyla	0.51	0.68	0.71	**0.67**
S. pentandra	0.54	0.57	0.85	**0.66**
S. x *mollissima*	0.42	0.57	0.85	**0.64**
S. x *reichardtii*	0.43	0.63	0.71	**0.63**
S. x *sericans*	0.47	0.52	0.85	**0.62**
S. eriocephala	0.48	0.52	0.85	**0.62**
S. x *calodendron*	0.38	0.61	0.71	**0.61**
S. myricoides	0.56	0.49	0.85	**0.61**
S. aegyptiaca	0.63	0.42	0.85	**0.58**
S. elaeagnos	0.49	0.41	0.85	**0.56**
S. myrsinifolia	0.56	0.38	0.85	**0.55**
S. matsudana	0.54	0.42	0.71	**0.53**
S. chilensis 'Fastigiata'	0.53	0.08	0.71	**0.33**
S. integra 'Hakuro-nishiki'	0.39	0.02	0.85	**0.33**
S. alba var. *caerulea*	0.47	0.02	0.71	**0.30**
S. x 'Boydii'	0.37	0	0	**0.04**

The highest ranked willows

The top fourteen ranked high risk willows in the national ranking (Table 9) were the same as the top fourteen ranked willows in the list of willows ranked according to their weighted invasiveness and impact scores (Table 8). The difference in order is due to the distribution scores of these taxa at a national scale, but clearly they are a high risk group whichever way you look at it.

Aside from their distribution scores, what makes these willows intrinsically higher risk than the other willows that were assessed?

Highly invasive willows

Very high invasiveness scores (Table 9) were achieved by five willow taxa:
subgenus *Vetrix*

- *S. nigra*
- *S. cinerea*
- *S. caprea*
- *S. purpurea*

(for more detailed information, see the document Invasiveness assessments, accompanying this report).

These willows tended to score high or moderately high for the same questions:

While most willows are described as heliophyllic [intolerant of shade] (Haines, 2004) and most taxa…must not be overhung by larger plants or trees (Newsholme, 1992), these five highly invasive willows could all establish under some canopy cover, which gives them a moderately high score for establishment (Question 2*).*
S. caprea was described as the most tolerant of shade (Skvortsov 1999), with *S. cinerea* able to establish “under dense wet sclerophyll forest" (Cremer 1999), whilst *S. nigra* has invaded heavily vegetated mountain streams (Cremer 1999) and *S. purpurea* can be "grown in deep shade" (Newsholme 1992).

Willows are generally described as “occurring in permanently or seasonally wet, inundated or waterlogged sites” (ARMCANZ 2001), which gives them a high score for life form (Question 4). Very few willows occur away from waterways and these include subgenus *Chamaetia*, that dominate the low alpine belt above the climatic timberline in Scandinavia (Dahl, 1987) and *S. integra* that occupies damp lowlands, never found close to flowing water (Skvortsov, 1999). These were the only assessed willow that scored low for this question.

Willows are often described as very fast growing (Brockmeyer 2007; Stott 1992) which gives them a high or moderately high score for growth rate (Question 7). However, most of the subgenus *Chamaetia* is described as relatively slow-growing (Newsholme 1992), and *S.* x ‘Boydii’ as very slow-growing (Newsholme 1992); the slowest growing willow (Kuzovkina & Quigley, 2004). So these two taxa alone scored low.

A female willow that has been fertilised by a compatible nearby male willow, with “a large crown would produce over 500,000 seeds (Cremer 1999). All the highly invasive willows were capable of setting seed and so scored high for Question 10 (number of propagules produced). Willows that are only present in Australia as male plants; *S. chilensis* and *S. fragilis* (Newsholme 1992; Cremer 1995), or are considered sterile; *S.* x *calodendron* and *S.* x *mollissima* (Cremer 1995; G. Carr, pers. comm.) scored low for this question.

Similarly, the ability to spread by seed gave all the highly invasive willows a high score for distribution questions (14 and 15), as "seed is easily carried by wind for more than 1km and some travels for up to 50km, or even 100km (Cremer, 1999), but even vegetatively propagating willows scored moderately high for Question 14, but only moderately low for Question 15.

The highly invasive willows were all capable of hybridising with naturalised willows in the wild, and *S. caprea* and *S. cinerea* are parents of the naturalised willow, *S.* x *reichardtii*. So all scored moderately high or high for Question 11.

Questions 2, 14 and 15 were considered particularly important factors in the invasiveness ability weeds, as is reflected in their relatively high weightings (Figure 4), particularly Question 2.

The two most invasive willow taxa: subgenus *Vetrix* and *S. nigra*; scored high or medium high for all invasiveness questions, although there were three moderate scores for *S. nigra*, as not enough information was found to answer those questions.

High impact willows

The impacts of willows was summarised in Section 2.2 of this report, as a result of analysing the results of the willows assessments from the Victorian Weed Risk Assessments.

Further information about a wider range of taxa was researched for the Willows Weed Risk Assessment (for more detailed information see the document Impacts assessments, accompanying this report). Several taxa scored high or moderately high for all impacts questions, including: *S.* x *rubens*, subgenus *Salix*, *S. nigra*, *S. alba*, *S. fragilis*, *S.* x *sepulcralis* and *S. babylonica* (although the latter had a medium score for Question 3 as not enough information was found to answer the question).

The other high impact taxa (See Table 9) scored high or moderately high for Questions: 2 - low amenity value; 4 - impact on recreation; 6 - causing erosion; 7 - reducing water quality, 8 - impact on structure; 9 - range of habitats impacted, and 10 - facilitating other invasive species. Questions 7, 8, 9 and particularly 6 were considered to be the most important factors in determining how seriously willows can impact on the environment (see weightings Figure 5).

Willows with high intrinsic scores (invasiveness and impact scores combined) tend to be those that establish in association with waterways and may tolerate canopy cover. They are fast-growing and can spread long distances by large quantities of seed. They also 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.

Confidence scores: how accurate is this data?

Confidence scores were calculated for each willow assessment, based on the quality of information that was used for the invasiveness and impact assessments. Figure 14 shows the relationship between confidence score and the combined invasiveness and impact scores.

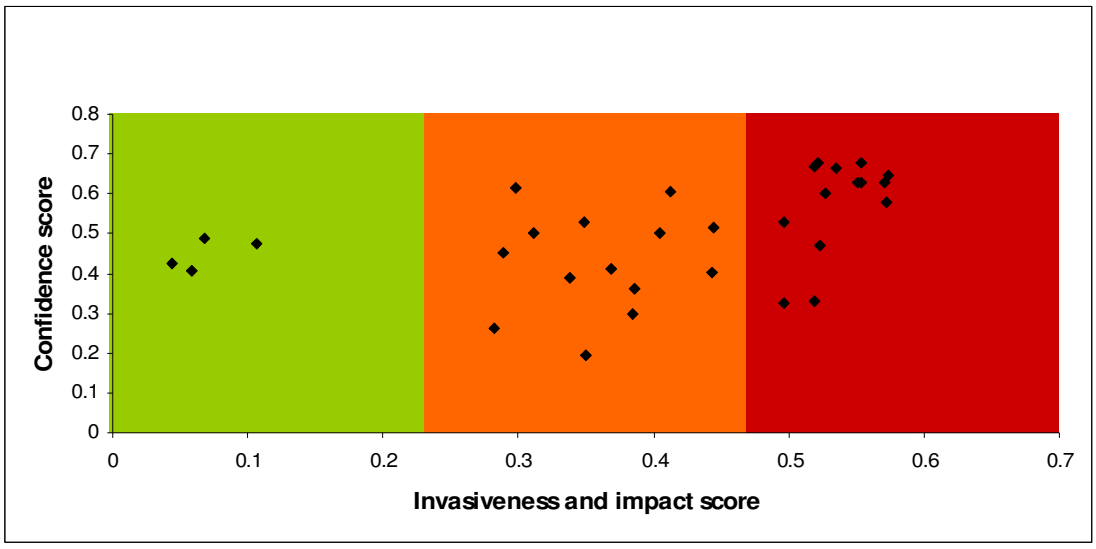

Figure 14: Confidence score vs invasiveness and impact scores

The confidence scores for each of the willow taxa are presented in Table 8 (above).

0.50 was the average confidence score for all the willows assessed. This indicates that overall, the quality of literature used in the assessments was of about the standard of information from general plant books, although some information was taken from very high quality references, and for some willow taxa there was no information at all to answer some questions. Most of the willows that had high invasiveness and impact scores also had above average confidence scores.

All of the willows that had low invasiveness and impact scores had below-average confidence scores. However, all of these willows, except for *S. chilensis* 'Fastigiata', are not known to be naturalised beyond their native range. The lack of information on the impacts of these willows is an indication that they may not have high impacts. However, there was also very little information available on the basic biology of these plants and for *S. integra* 'Hakuro-nishiki,' *S.* x 'Boydii', and the subgenus *Chamaetia* in particular, there was no information found to answer almost half of the invasiveness questions. Further research on these willow taxa is required before they can be considered truly low risk.

A moderate score for invasiveness and impact can be interpreted in two ways. At first glance it would appear that a moderate score indicates that a willow poses a moderate risk in terms of its invasiveness and impacts. However, it could also indicate that there was very little information available about the taxon, so it was often given a medium score, for "don't know". In Table 8, there are several taxa that appear to have a moderate invasiveness and impact risk, but their low confidence scores indicate that, while this might be a true indication of their risk, it is just as likely that they pose a greater or smaller risk as is indicated here. This includes *S. myricoides*, *S. myrsinifolia, S. pentandra, S.* x *calodendron* and *S.* x *sericans*. These taxa should be a priority for further research as they may pose a greater risk than their assessments currently indicate.