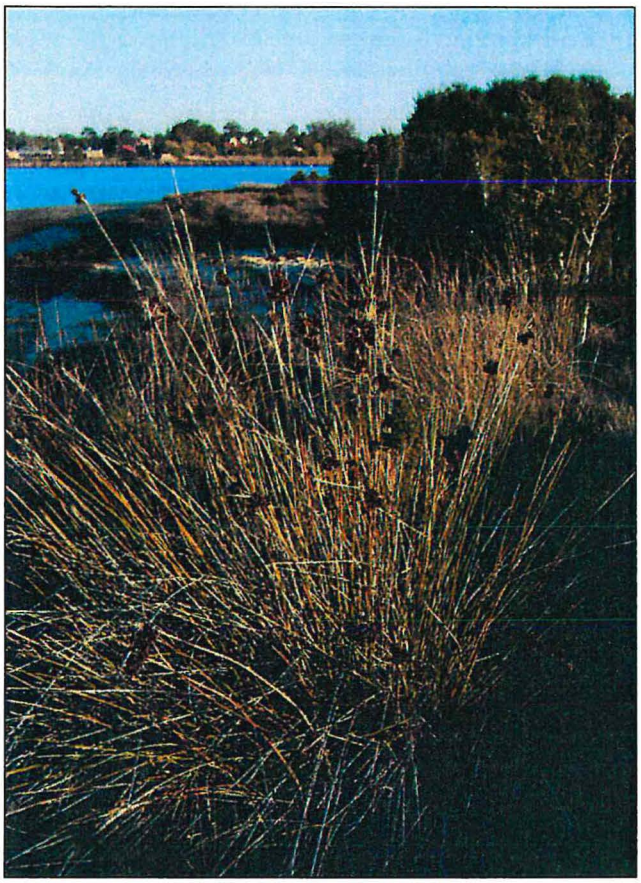
Managing Sharp Rush *(*Juncus acutus)*



***Juncus acutus* on the edge of the Swan River Estuary at Point Waylen, Alfred Cove**
Photograph - Michael Lyons

Department of Environment and Conservation

Proceedings of a workshop held at
Wollaston College Conference Centre, Mt Claremont
Perth, Western Australia
Friday 4 August 2006

Edited by Vanda Longman

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INTRODUCTION

On Friday 4 August 2006, the Department of Environment and Conservation (DEC) held a one day workshop on managing the weed Sharp or Spiny Rush *(*Juncus acutus)*.

Why should Sharp Rush be the subject of a workshop in Western Australia (WA)?

A chapter in the book *Noxious Weeds of Australia* (Parsons and Cuthbertson 1992) is devoted to Spiny (Sharp) Rush, where the authors note:

"It appears to be troublesome only in Australia, although there are occasionally reports from New Zealand and Argentina of its potential as a weed. In Australia, it occurs commonly in New South Wales, Victoria and South Australia, particularly on low fertility disturbed areas such as mine dumps, coastal flats and other moist low-lying sites, especially if saline."

But, with reference to WA, this section concludes with the following statement.

"Spiny Rush also occurs in Western Australia but is not considered weedy."

That is, while its major area of occurrence in WA is in the Agricultural Zone, these populations are considered confined to secondarily salinised-cleared waterways and flats. The paper present by Michael Lyons will demonstrate that this is still true.

However, sadly, currently Sharp Rush is rapidly expanding its range. Populations have been found on the Swan Coastal Plain where it is invading high quality riverine, estuarine and saline marsh habitats, displacing native species. This spread is being facilitated by human activities, soil movement and active plantings through mis-identification, as several presentations demonstrate.

A knowledge of the rushes of WA, both weedy and native, the biology and control of Sharp Rush and its potential spread is needed amongst admirers, friends and managers of our natural regions.

If this workshop alerts anyone to the threat Sharp Rush poses to our city and regional estuarine, brackish and saline wetlands, and helps prevent these habitats being invaded, then it will have served a useful purpose.

REFERENCES

Parsons WT and Cuthbertson EG (1992) *Noxious Weeds of Australia*. Inkata Press, Melbourne.

Greg Keighery

PARTICIPANTS

Forty-eight people registered for the workshop. These people, and the speakers, are listed below.

Name	Position	Organisation
Kellie Agar	Project Coordinator Environmental Weeds	Department of Environment and Conservation
Karen Bettink	Project Officer (Urban Nature)	Department of Environment and Conservation
Emma Bramwell	Covenanting Coordinator	Department of Environment and Conservation
Greg Bremner	Principal Coordinator Environmental Operations	City of Gosnells
David Bright		REGEN4
Kate Brown	Bushland Management Advisor (Urban Nature)	Department of Environment and Conservation
Robin Campbell		
Vanessa Clarke	Conservation Officer	Department of Environment and Conservation
Diana Corbyn	Advanced Skills Lecturer	Challenger TAFE
Jill Cowcher	Farmer	Williams
Thelma Crook	River Recovery Coordinator	Greening Australia
Julia Cullity	Biodiversity Action Learning Program Coordinator	Greening Australia
Georgia Davies	Natural Resource Management Officer	Swan River Trust
Bob Dixon	Manager Biodiversity and Extensions	Botanic Gardens and Parks Authority
Prudence Duffy	Revegetation Officer	Department of Water
Alison Dugand		
Darralyn Ebsary		
Val English	Acting Principal Ecologist	Department of Environment and Conservation
Fiona Falconer	Land For Wildlife & Communications Officer	Department of Environment and Conservation

Name	Position	Organisation
Fiona Felton	Nature Conservation Officer	Department of Environment and Conservation
Alex Hams		Peel Harvey Catchment Council
Carolyn Harding	Environmental Officer	Department of Environment and Conservation
Susan Harris		Ecomedia
Roweena Hart	Natural Resource Management Officer	Swan River Trust didn't actually attend
Vicky Hartill	Wetland Officer	City of Wanneroo
Melissa Hoskins	Conservation Officer	Department of Environment and Conservation
Penny Hussey	Senior Project Officer, Land for Wildlife	Department of Environment and Conservation
Bob Huston	Nature Conservation Officer	Department of Environment and Conservation
Vanessa Jackson	Assistant Environmental Officer	Department of Defence
Helen Job		
Mike Johnson	Rivercare Officer	Department of Environment and Conservation
Ted Johnson	Lecturer	Swan TAFE
Anthea Jones	Principal Technical Officer (Wetlands)	Department of Environment and Conservation
Penny Keenan	Officer (Minyalo Brook)	Midland NRM
Bronwen Keighery	Leader Swan Bioplan Project	Department of Environment and Conservation
Greg Keighery	Principal Research Scientist	Department of Environment and Conservation
Margaret Langley	Technical Officer	Department of Environment and Conservation
Bethan Lloyd	Community Landcare Support Officer	Toodyay Land Conservation District Committee

Name	Position	Organisation
Mike Lyons	Research Scientist	Department of Environment and Conservation
Michael MacShane	Avon Revegetation Officer	Greening Australia
Diane Matthews	Vice President	Canning River Residents Environment Protection Association
Linda Metz	Regional Operations Manager, Perth	Conservation Volunteers Australia
Renee Miles	Operations Officer	Department of Environment and Conservation
David Mort	Horticulture Technical Officer	City of Rockingham
Bill Muir	Senior Technical Officer	Department of Environment and Conservation
Gavan Mullan	Revegetation Officer	Department of Environment and Conservation
Myles Mulvay		Department of Environment and Conservation
Fleur Patterson	Environmental Officer	City of Melville
Liz Penter	Perth Biodiversity Project Technical Officer	Greening Australia
Dorothy Perret		
Jill Pryde	Acting Senior Ecologist	Department of Environment and Conservation
Rebecca Ryan	Environmental Officer	Department of Environment and Conservation
Elaine Sherry	Farmer	Boddington Shire
Nicole Siemon		NSA Association
John Snowden	Project Officer	Department of Environment and Conservation
David Steadman	Grazier	Landcare Officer
Craig Wansbrough	Natural Resource Management Officer	Eastern Metropolitan Regional Council

THE WORKSHOP

Before lunch, expert speakers presented papers on native and naturalised rushes of Western Australia and on the biology, distribution and control of Sharp Rush. After lunch, representatives from a community group, the Department of Defence and local government presented three case studies regarding control of Sharp Rush. The powerpoint presentations delivered at the workshop are contained in the CD accompanying copies of the proceedings held in libraries.

A new "Managing Weeds in Bushland" brochure, specifically produced by Urban Nature and DEC for Sharp Rush, was launched. There followed a discussion session, facilitated by Greg Keighery, in which the participants of the workshop were invited to comment on research and monitoring requirements, strategies to limit spread of Sharp Rush, the feasibility of eradicating new populations and procedures to ensure correct material is used in revegetation.

ACKNOWLEDGEMENTS

This workshop and publication has relied on the support of the following individuals and groups.

- Staff of Wollaston Conference Centre for assistance and the provision of a pleasant venue.
- Urban Nature (DEC Swan Region) for assistance in promotion, bookings and logistics, especially Graznya Paczkowska and Karen Bettink.
- Swan Bioplan (DEC) for assistance in obtaining the venue and producing the proceedings.
- The people who registered for, and participated in, the workshop.
- Authors and presenters of the papers at the workshop.

Department of Environment and Conservation Workshop

Managing Sharp Rush (**Juncus acutus*)

Friday 4 August 2006
8:30am - 3:30pm
Wollaston College Conference Centre
Mount Claremont

Illustrations: K.Bettink

This free workshop presented by the Department of Environment and Conservation (DEC) will provide an opportunity to consider ways to control and limit the spread of Sharp Rush (**Juncus acutus*) into wetlands and estuaries of the Swan Coastal Plain to Albany.

A series of case studies will allow participants to gain an understanding of:

- native and weedy rushes of Western Australia, including guidelines for identification;
- spread and impact of Sharp Rush in Australia and particularly Western Australia (this species has potential impacts on the ecology and recreational use of the waterways from Perth to Augusta);
- ecology and control of Sharp Rush; and
- experiences of government (local, State and Federal) and Friends groups in dealing with invasions.

Speakers and topics include:

Greg Keighery, DEC and **Bronwen Keighery**, DEC – Native and naturalised *Juncus* in Western Australia. Current status and potential spread of **J. acutus*.
Michael Lyons, DEC – The current distribution of **J. acutus* and aspects of its occurrence in the SW agricultural zone.
Kate Brown and Karen Bettink, DEC - Biology of Sharp Rush, **J. acutus*.
Bob Dixon, Botanic Gardens & Parks Authority (BGPA) - Control of Sharp Rush, **J. acutus*.
Roweena Hart, Swan River Trust – Swan River foreshore assessment.
Dianne Matthews, Canning River Residents Environment Protection Association (CRREPA) – **J. acutus* masquerading as *J. pallidus*: CRREPA experiences.
Vanessa Jackson and Joanne Wann, Department of Defence - Eradicating **J. acutus* from Garden Island.
Greg Bremner, City of Gosnells – **J. acutus* masquerading as *J. pallidus*: the Gosnells experience.

A group discussion will be held to ascertain research and monitoring requirements, investigate strategies to limit spread, determine feasibility of eradicating new populations and outline procedures to ensure correct material is used in revegetation.

Contact the Department of Environment and Conservation's Swan Region

on 9368 4399
or Urban.Nature@dec.wa.gov.au
Registrations essential, by 28 July 2006

Department of
Environment and Conservation

Department of Environment and Conservation

Managing Sharp Rush *(*Juncus acutus)* Workshop Program

Friday 4 August 2006
Wollaston College Conference Centre
Mt Claremont

BACKGROUND

8.45 - 9.00 Introduction

9.00 - 9.30 Native and naturalised *Juncus* in Western Australia, Greg Keighery and Bronwen Keighery (Department of Environment and Conservation, DEC)

9.30 - 9.50 The current distribution of **J. acutus* and aspects of its occurrence in the SW agricultural zone, Michael Lyons (DEC)

9.50 – 10.20 Current status and potential spread of **Juncus acutus*, Greg Keighery, Bronwen Keighery (DEC)

10.20 - 10.50 Biology of Sharp Rush, **Juncus acutus*, Kate Brown, Karen Bettink (DEC)

Morning Tea

11.25 - 11.55 Control of Sharp Rush, **Juncus acutus*, Bob Dixon (Botanic Gardens & Parks Authority, BGPA)

11.55 - 12.20 Swan River foreshore assessment, Roweena Hart (Swan River Trust)

Lunch

CASE STUDIES

1.00 - 1.20 **Juncus acutus* masquerading as *J. pallidus*: CRREPA experiences, Diane Matthews (Canning River Residents Environment Protection Association, CRREPA)

1.20 - 1.40 Eradicating **Juncus acutus* from Garden Island, Vanessa Jackson and Joanne Wann (Department of Defence)

1.40 – 2.00 Launch of new EWAN/DEC "Managing Weeds in Bushland: Sharp Rush, **Juncus acutus*" brochure, Diane Matthews and Karen Bettink

2.00 - 2.20 **Juncus acutus* masquerading as *J. pallidus*: the Gosnells experience, Greg Bremner (City of Gosnells)

2.20 - 3.20 Discussion (Facilitator Greg Keighery): research and monitoring requirements, strategies to limit spread, feasibility of eradicating new populations and procedures to ensure correct material is used in revegetation.

3.20 Afternoon Tea & Close

Department of
Environment and Conservation

Native and naturalised *Juncus* in Western Australia

Greg J. Keighery[1] and Bronwen J. Keighery[2]

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Bronwen.Keighery@dec.wa.gov.au

SUMMARY

Twenty six species of *Juncus* are known from Western Australia, including two (*Juncus prismatocarpus* subsp. *prismatocarpus* and *J. procerus*) that have no collections in the Western Australian Herbarium. Another two (**J. gerardii* and **J. effusus*) have been recorded for Western Australia but require confirmation. Of these, 10 are weeds, mostly either pasture weeds (such as **J. polyanthemos* and **J. usitatus)* or weeds of disturbed wetlands *(*J. articulatus* subsp. *articulatus*, **J. oxycarpus* and **J. microcephalus)*. However, most have been recorded from relatively undisturbed fresh water wetlands. The most widespread weeds are the annuals **J. capitatus*, **J. hybridus* and forms of **J. bufonius*, which are often recorded in bushland. Both **J. acutus* subsp. *acutus* and **J. imbricatus* are invading relatively undisturbed calcareous or saline wetlands, which have few major weeds.

The effects of these weedy *Juncus* species are poorly documented and require more study. Many *Juncus* species seem to be actively extending their ranges and a priority should be to limit this spread.

INTRODUCTION

The genus *Juncus,* with about 315 species, is one of the largest genera in the Monocotyledons. The genus is almost cosmopolitan in distribution, but uncommon in the tropics and absent from Antarctica. The major centres of diversity of the genus are western North America, the Mediterranean region of Europe, the Sino-Himalayan Region, the Far East, South Africa and South-Eastern (SE) Australia/New Zealand.

Interestingly, the type species of the genus is *Juncus acutus* subsp. *acutus* from the subgenus *Juncus*. There has been a considerable amount of work on the genus over the last 15 years, including reviews of:

- the subgenus *Juncus* by Snogerup in 1993;
- *Juncus* species worldwide by Kirscher (2002a and b); such reviews of cosmopolitan genera are very challenging and not often completed; and
- information on Australasian species' complexes by Wilson and Johnson in 2001.

Despite this effort, many *Juncus* species are still difficult to separate. These difficulties are related to: the geographical and ecological variants found in the widespread species; frequent occurrence of hybridisation; and the use of often obscure vegetative characters to separate taxa. Of use in distinguishing the taxa are illustrated keys to the majority of the Australian species in several State floras, especially those for South Australia (Jessup and Toelken 1986), New South Wales (Wilson *et al.* 1993) and Victoria (Albrecht and Walsh 1994). A series of illustrations, maps and photos were presented at the workshop. These were sourced from these papers and books. A set of illustrations and

maps of the Western Australian *Juncus* species, to help with identification, were available at the workshop.

This paper is not intended to repeat information that is available in the above references; rather we will briefly review the weedy and native species present in Western Australia (WA).

WESTERN AUSTRALIAN SPECIES

There are 26 species of *Juncus* recorded in WA (Table 1) from two subgenera and eight sections. These comprise 17 native species and 10 weeds (*J. bufonius* is both a native and a weed). Populations of *Juncus* species are largely confined to temperate WA. One species, *J. meianthus*, is endemic to WA.

The species are briefly described below, following the arrangement in Table 1. The species are ordered in subgenera, annuals/perennials and sections. The most obvious, reliable character that distinguishes the sections is the leaves and this ordering is taxonomically valid, as well as being a useful guide to identification.

Subgenus *Juncus*

Annuals

Section Caespitosi (one weed species)

This is the first of two sections of annual species in the genus.

- **J. capitatus* is a widespread leafy annual found throughout southern WA, in pastures, seasonal wetlands (granite outcrops, clay flats and edges of salt lakes) and woodland flats on heavy soils. It is native to Europe east into South-West Asia to Kazakhstan, and there are scattered records throughout Africa. It is a weed in North and South America, Australia and New Zealand (NZ).

Perennials

Section Juncus (one native and one weed species)

There are two terete leaved species from the subgenus *Juncus* present in WA.

- *J. kraussii* subsp. *australiensis*
- **J. acutus* subsp. *acutus*

For further information, see the papers dealing with **Juncus acutus* in WA (Keighery and Keighery, and Lyons, this publication).

Section Graminifolii (three native species)

Three species of grassy leaved perennials from the section Graminifolii are recorded for WA.

- *J. caespiticius,* with narrow terete leaves, occurs throughout southern WA, South Australia (SA), Tasmania (Tas), Victoria (Vic) and NZ.
- *J. meianthus* is confined to permanently wet sites in southern WA from the Stirling Ranges to Augusta.
- *J. planifolius,* with flat leaves, occurs in southern WA, SA, Tas, Vic, NZ, Juan Fernandez Islands and Chile. This species is a weed in Hawaii, Oregon and Ireland.

Section Iridifolii (one native or weed species)

- *J. prismatocarpus* subsp. *prismatocarpus* (Figure 1), a species with flat or Iris-like leaves, is not listed as a Western Australian species on FloraBase (Western Australian Herbarium 1998-). However, there is a herbarium record from the Murchison River in Kew Herbarium in the United Kingdom and another from the Swan River in the National Herbarium of New South Wales (NSW). It is possible that these were failed naturalising populations or are true records of a rarely recorded species.

Section Ozophyllum (one native and three weed species)
There are four species with articulated leaves (hollow tubes with ribs) from section Ozophyllum recorded for WA.

- *J. holoschoenus* is the only native member of this group and occurs from Perth to Albany in southern WA, and in SA, Tas, NSW, Vic and NZ. Interestingly *Juncus holoschoenus* has tuberous roots (Pate and Dixon 1982). This rarely recorded feature of the species is significant as these roots are a major waterbird food source.
- **J. microcephalus* is closely related to *J. holoschoenus*. **J. microcephalus* is native to North and South America and is weedy in southern WA (from Perth to Esperance), SA, Tas, NSW and Vic (Figure 2). This species is a common weed of disturbed and eutrophic wetlands of southern WA, including dams and roadside ditches. There is concern that **J. microcephalus* may both hybridise with and displace *J. holoschoenus* from waterbird habitats. Disturbingly, all accounts of the genus *Juncus* in Eastern Australia note that **J. microcephalus* is rapidly spreading in those areas.
- **J. oxycarpus* is native to Africa but is naturalised and spreading in southern Australia. In WA it has been recorded from Perth to Albany in creeks, edging seeps and wetlands along the south coast and is probably more common than currently recorded.
- **J. articulatus* subsp. *articulatus* is a very widespread species throughout the northern hemisphere and is considered introduced into southern Australia and New Zealand (Figure 3). In WA it is known from disturbed creeklines and wetlands, but it is also invading natural claypans, riverine sites and creeklines.

Subgenus *Agathryon*

Annuals

Section Tenageia (one native species which also behaves as a weed, and one weed species)
This is the second of the two annual sections of the genus. The section Tenageia currently contains two leafy annual species, *J. bufonius* and **J. hybridus*. The taxonomy of this group remains complex and many local variants are known from Australia and elsewhere.

- *J. bufonius* is the most widespread member of the genus, being found almost throughout the generic range (Figure 4). In WA it is found south and west of a line between Shark Bay, Kalgoorlie and Eyre, in numerous habitats. The species is naturally weedy and it is highly probable that both native and introduced forms are present in Australia.
- **J. hybridus* is a recognised 'form' of *J. bufonius* (Figure 5) and is a European species introduced to the southern hemisphere. This species occurs throughout southern WA in disturbed wetlands but is probably more common than recorded.

Perennials

Section Steirochloa (one weed species)
This section has a few long basal leaves.

- **J. imbricatus* is native to South America and a weed in Southern Africa, Portugal, New Zealand and southern Australia. This is a poorly known weed in WA, with a few records from pastures and roadsides near Denmark. However, we have recently recorded this weed from calcareous wetlands in Chandala Nature Reserve near Muchea, suggesting it may be much more widespread and invasive than currently recorded.

**J. gerardii* is frequently mentioned as a weed in WA in other floras (Albrecht and Walsh 1994 and Richardson *et al.* 2006) but we are not aware of any authenticated records.

Section Juncotypus (10 native and two weed species)
The largest group of *Juncus* species in WA comprises the leafless perennials of Section Juncotypus. This group is most species-diverse in SE Australia. This group is the most difficult to key as they are morphologically plastic, readily hybridise and require stem sections to key out successfully. The floras of New South Wales (Wilson *et al.* 1993) and Victoria (Albrecht and Walsh 1994) are most useful in separating these.

All species native to WA are also found elsewhere, as listed below. Species also native to SE Australia include:

- *J. aridicola*
- *J. gregiflorus*
- *J. radula*

Species also native to SE Australia and NZ include:

- *J. amabilis*
- *J. flavidus*
- *J. filicaulis*
- *J. pallidus*
- *J. pauciflorus*
- *J. subsecundus*

Species also native to SE Australia, NZ and South America include:

- *J. procerus* (Figure 6). Although it is not listed for WA in FloraBase (Western Australian Herbarium 1998-), there are two collections from WA in the Melbourne and Sydney herbaria. This species has been introduced into Western Europe.

Included in this section are two weeds, both of which are native to Eastern Australia:

- **J. usitatus* is a widespread weed which occurs in ditches, irrigation channels, pastures and disturbed wetlands from Perth to Albany.
- **J. polyanthemos* is uncommon, only being known from irrigated pastures on the Swan Coastal Plain south of Perth around Harvey. Here these two species and hybrid derivatives are common pasture weeds.

**J. effusus* is often listed from WA, but there are no authentic records for this state. This species is a widespread species from North and South America and Europe, introduced to southern Australia and New Zealand.

WESTERN AUSTRALIAN WEEDY SPECIES

Documentation and research

Information on the distribution and effects of the 10 weed species of *Juncus* in WA is incomplete and requires considerably more documentation and research. This is well illustrated by several examples.

- Some species groups at first appear to show distinct habitat preferences. **J. polyanthemos* and **J. usitatus* are largely pasture weeds and **J. articulatus* subsp. *articulatus*, **J. oxycarpus* and **J. microcephalus* are weeds of disturbed fresh water wetlands. However, all of these species have been recorded as invading natural relatively undisturbed wetlands.
- The most widespread weed is the annual **J. capitatus*, which is often recorded in bushland but its effects are unknown. The same applies to the other annuals **J. hybridus* and forms of *J. bufonius*.

Information from eastern Australia is similarly brief and, at times, contradictory.

Juncus weeds of concern

Both **J. acutus* subsp. *acutus* and **J. imbricatus* are invading relatively undisturbed calcareous or saline wetlands, which have few major weeds. In the future, our worst weeds from an environmental viewpoint will probably be **J. acutus* subsp. *acutus*, **J. microcephalus* and probably **J. imbricatus*.

Many *Juncus* species, not already established in WA, seem to be actively extending their ranges. The priority for control of these species is to limit their spread. For example, there are 20 species of weedy rushes present in SE Australia (Richardson *et al.* 2006), of which 10 *(*J. acuminatus*, **J. bulbosus*, **J. capensis* var. *micranthus*, **J. effusus*, **J. inflexus*, **J. tenuis*, **J. capillaceus*, **J. cognatus*, **J. fontanesii* and perhaps **J. gerardii)* have not been recorded in WA. Wilson *et al.* (1993) also list **J. acutiflorus* and

**J. canadensis* as naturalised near Wentworth Falls in NSW. Csurhes and Edwards (1998) note that **J. acutiflorus* may have similar weed potential to **J. acutus* subsp. *acutus*. The success of some of these extra species is due to SE Australia being both wetter and colder than southern WA, but it suggests that many more weedy rushes are capable of being introduced into WA.

REFERENCES

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TABLES

Table 1 Western Australian *Juncus* species.

Subgenus *Juncus*

Annuals

Sideways heads of flowers (Sect. Caespitosi)

**Juncus capitatus*

Perennials

Terete leaved (Sect. Juncus)

J. kraussii subsp. *australiensis*

**J. acutus* subsp. *acutus*

Many grass-like leaves (Sect. Graminifolii)

J. caespiticius

J. meianthus

J. planifolius

Flat Iris-like leaves (Sect. Iridifolii)

J. prismatocarpus subsp. *prismatocarpus*

Articulated leaves (Sect. Ozophyllum)

J. holoschoenus

**J. microcephalus*

**J. oxycarpus*

**J. articulatus* subsp. *articulatus*

Subgenus *Agathryon*

Annuals

Small grassy annuals (Sect. Tenageia)

J. bufonius

**J. bufonius*

**J. hybridus*

Perennials

Few leaved (Sect. Steirochloa)

**J. imbricatus*

Leafless, flower in summer (Sect. Juncotypus)

J. amabilis

J. aridicola

J. filicaulis

J. flavidus

J. gregiflorus

J. pallidus

J. pauciflorus

J. procerus

J. radula

J. subsecundus

**J. polyanthemos* (introduced from Eastern Australia)

**J. usitatus* (introduced from Eastern Australia)

FIGURES

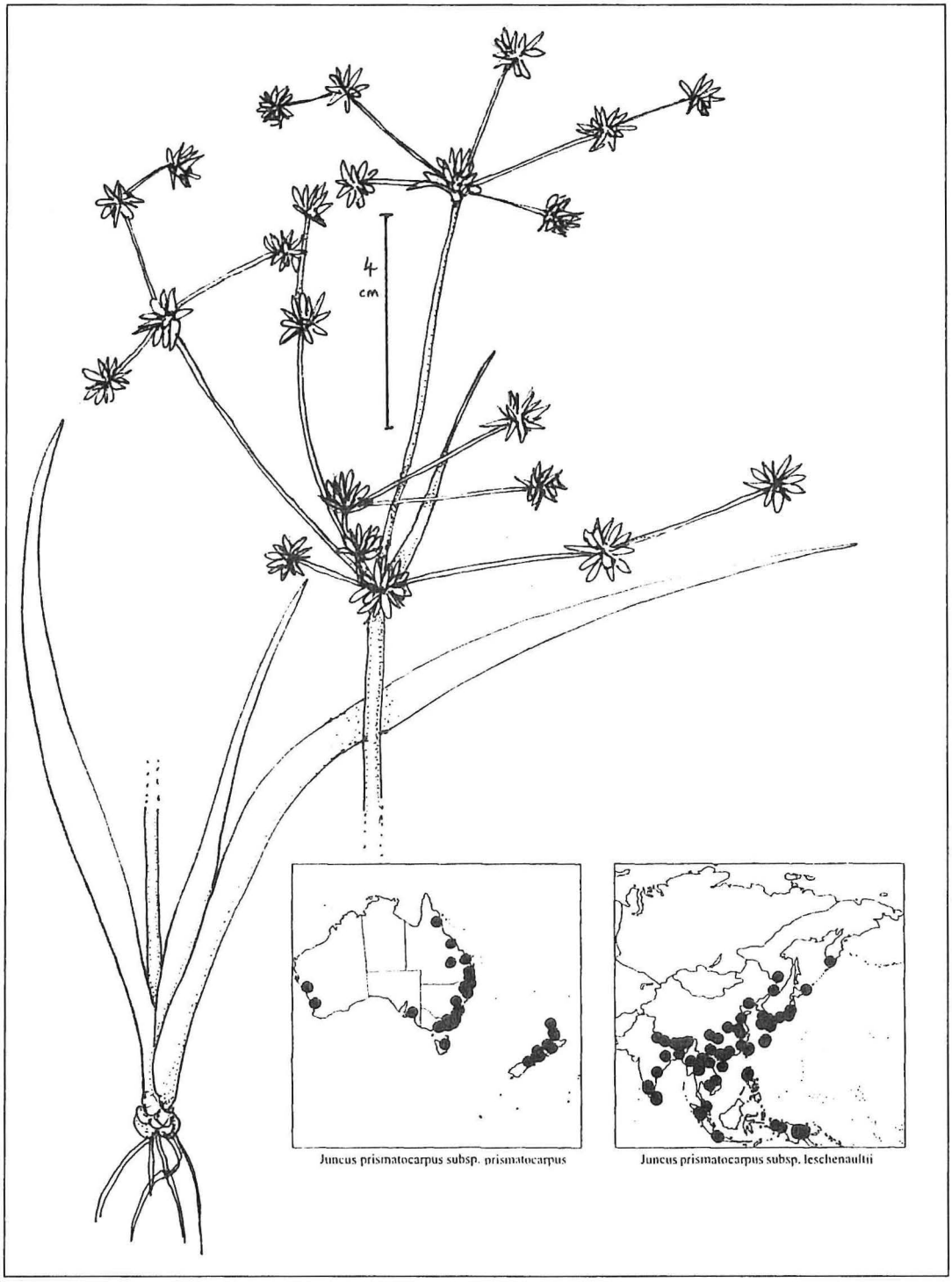

Figure 1. ***Juncus prismatocarpus*** **subsp.** ***prismatocarpus.*** **Plant drawn from an image on the Hornsby Shire Council's Online Herbarium (Hornsby Shire Council, NSW 1998-). Maps of the distribution of** ***J. prismatocarpus*** **subspecies, adapted from Kirscher (2002a).**

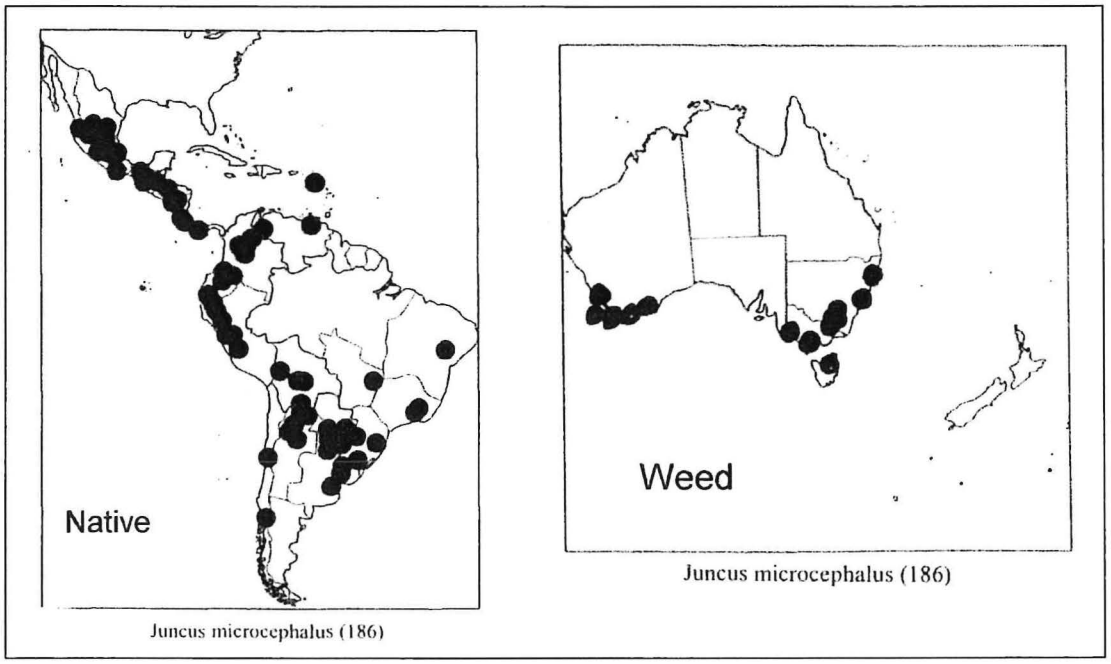

Figure 2. Distribution map of ****Juncus microcephalus* **(Kirscher 2000a).

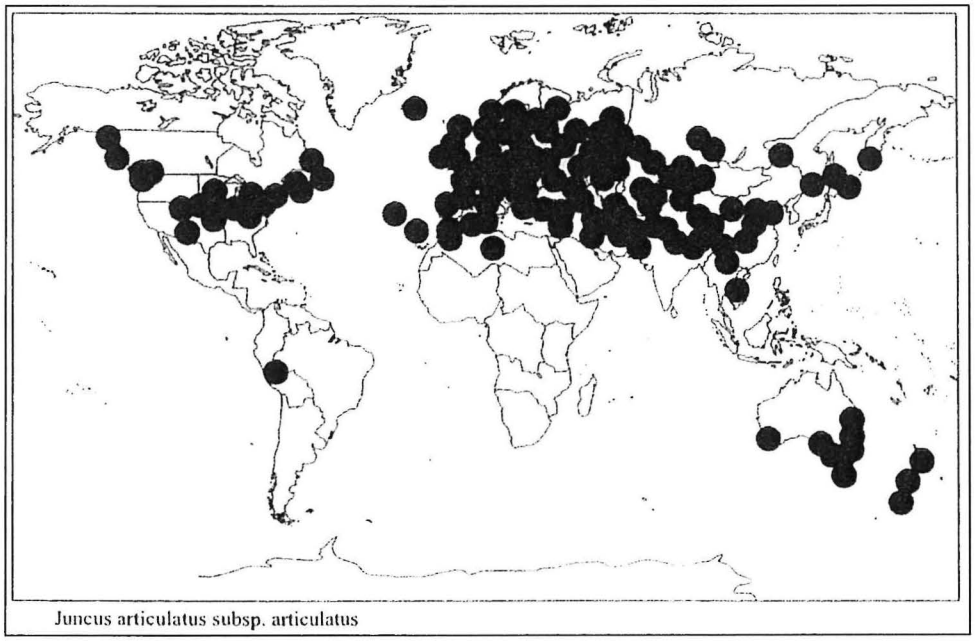

Figure 3. Distribution map of ****Juncus articulatus* **subsp. ***articulatus*** **(Kirscher 2000a).**

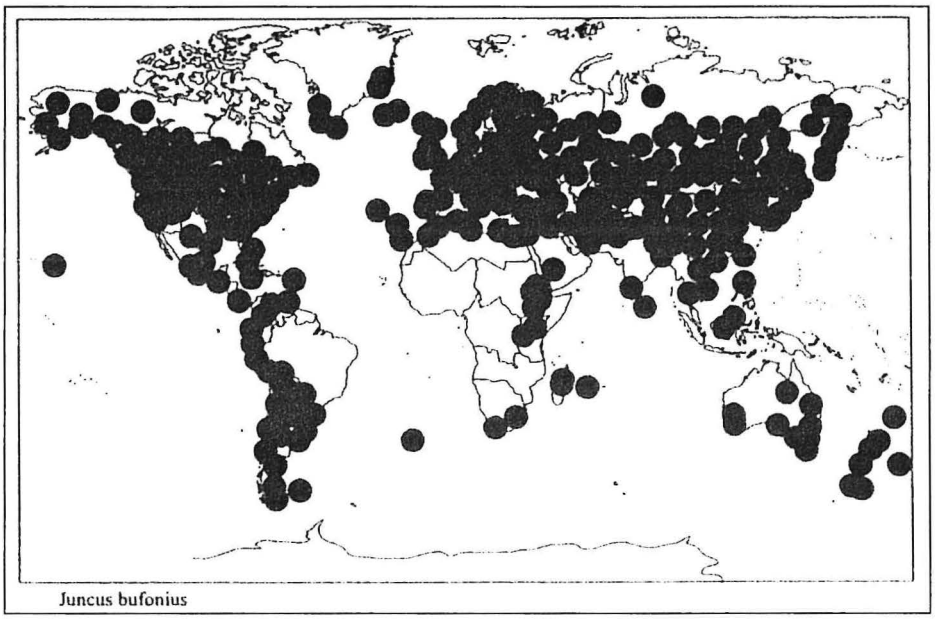

Figure 4. Distribution map of *Juncus bufonius* (Kirscher 2002b).

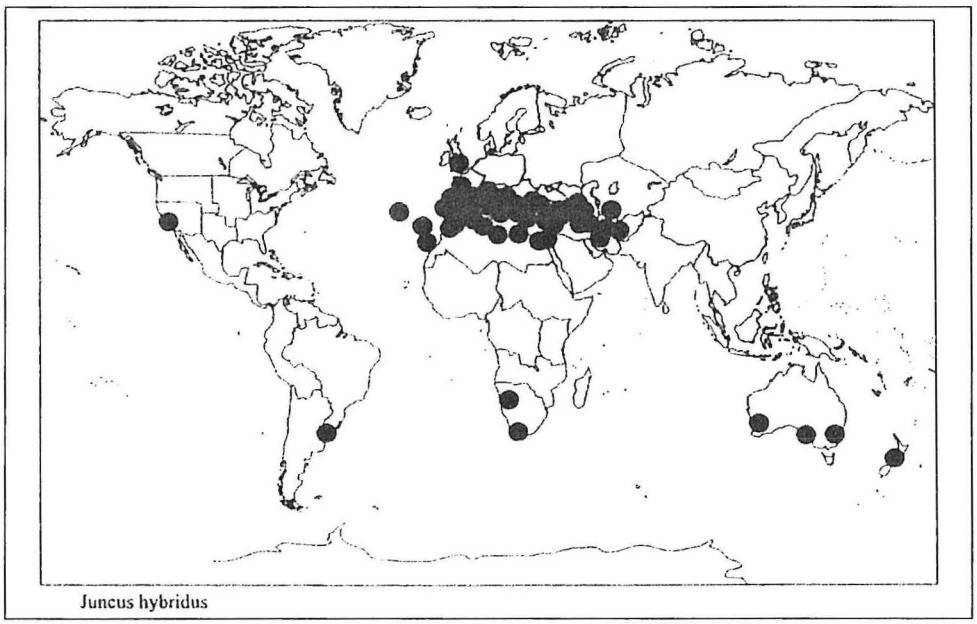

Figure 5. Distribution map of **Juncus hybridus* from Kirscher (2002b).

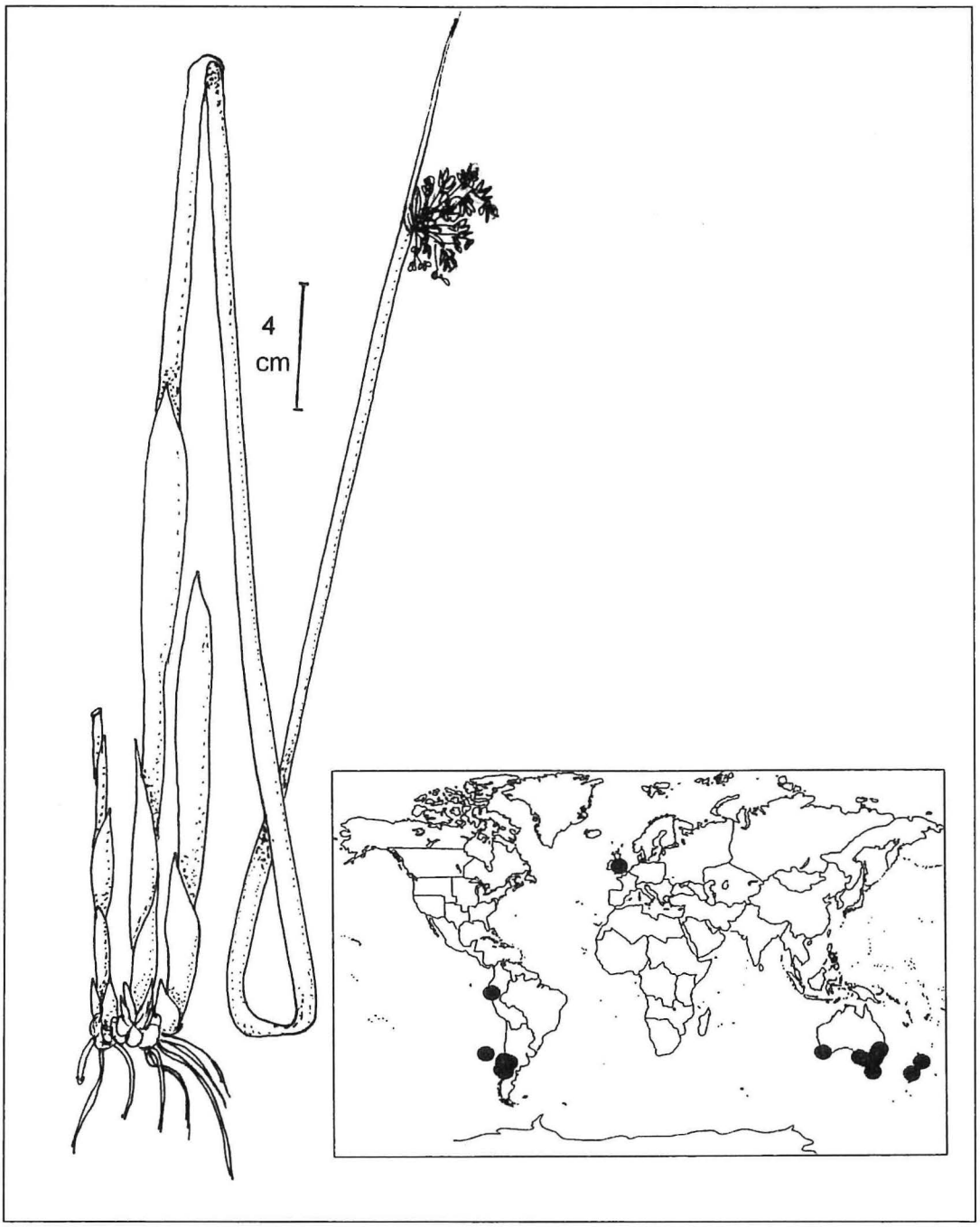

Figure 6. *Juncus procerus.* Plant drawn from an image on the Hornsby Shire Council's Online Herbarium (Hornsby Shire Council, NSW 1998-). Distribution map of *Juncus procerus* from Kirscher (2002b).

The current distribution of **Juncus acutus* and aspects of its occurrence in the SW agricultural zone

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SUMMARY

**Juncus acutus* is widespread in the agricultural zone of south-western Australia. In this area it predominantly occurs in disturbed and hydrologically altered wetlands that are typically permanently wet and/or salinised. These sites are generally species-poor and dominated by naturalised taxa. Areas of groundwater discharge with intermediate soil salinity appear particularly susceptible to invasion.

INTRODUCTION

A major biological survey of the Western Australian south-west agricultural zone (SWAZ) was undertaken between 1998 and 2001 to document the biodiversity of the region, investigate the impact of dryland salinity on biodiversity values and recommend catchments for intensive management for biodiversity conservation (Keighery *et al.* 2004). Since hydrological change and salinisation would have most impact on the low lying portions of the landscape there was a special effort to survey the wetlands of the area (Lyons *et al.* 2004). All major wetland types were sampled and included fresh, naturally saline or brackish wetlands, and secondarily saline and secondarily brackish wetlands.

The floristic and environmental data from the survey are used here to examine the distribution of **Juncus acutus* in the SWAZ and highlight the attributes of the wetlands where it occurs.

RESULTS AND DISCUSSION

Herbarium records show **J. acutus* is widespread throughout the agricultural zone with numerous additional occurrences on the Swan Coastal Plain. Outlying records include the West Dalyup River west of Esperance, Chilimony Nature Reserve NW of Northampton, and near the Mitchell River north of Denmark (Figure 1).

The survey of the SWAZ coincided with the core distribution of **J. acutus* as revealed by the herbarium data. Two hundred and fourteen wetlands were intensively sampled with 813 quadrats established to sample the major vegetation zones at each wetland (Figure 2). **J. acutus* was recorded from 21 quadrats at 14 of the 214 wetlands sampled (Figure 3).

Cluster analysis of the quadrat data produced a detailed classification of 26 major 'site' groups based on their species composition. **J. acutus* occurred in four of the quadrat groups (12, 14, 15 and subgroup 22.1) that could be broadly described as disturbed and artificial wetlands with some saline influence (Lyons *et al.* 2004). They included creeklines, dams, saline seeps, and disturbed secondary saline/brackish wetlands. These sites were species poor (3-14 taxa/quadrat) and dominated by naturalised species.

Many of these wetlands were areas of groundwater discharge. Although not directly measured these sites were likely to provide year-round soil moisture availability since many of the wetlands also held

water semi-permanently or permanently, an uncommon occurrence for wheatbelt wetlands. Notably the naturally saline wetlands systems of the SWAZ do not appear susceptible to invasion by *J. acutus*, and this may reflect a general lack of soil moisture over summer. Some valuable naturally saline groundwater fed wetlands however, such as Boases Salt Seep, would appear particularly at risk of future invasion.

The occurrence of *J. acutus* in relation to quadrat soil salinity, wetland salinity (of the waterbody) and annual rainfall are shown in Figures 4 and 5. Within the SWAZ, *J. acutus* was recorded between 300-600 mm annual rainfall, at wetlands that were predominantly brackish, although fresh and saline sites were also invaded (Figure 4). Wetland salinity however does not always reflect the substrate salinity on the margin of the waterbody and the relationship between occurrence and substrate salinity shows a more defined preference for intermediate salinity soils (Figure 5).

Cluster analysis was also performed which grouped species into 29 assemblages based on their pattern of co-occurrence at quadrats (Lyons *et al.* 2004). **Juncus acutus* was a member of species assemblage 2.7 of Lyons *et al.* (2004). The component species of the assemblage are wetland associated plants and include **J. acutus*, **Rumex crispus*, **Symphotrichum subulatum*, *Typha domingensis*, *Puccinellia stricta* and *Boloboschoenus caldwellii*. Most are species of the mesic south-west and extend into the western Wheatbelt in suitable habitats, but do not extend into semi-arid zone. The largest occurrences of this assemblage are in the central and south-western Wheatbelt (Figure 6).

During the survey **J. acutus* was widely observed in areas with little free or open water. These sites were not suitable for sampling but represented large areas of mid-slope and valley floor groundwater discharge often in cleared paddocks, but also along valleys with remnant vegetation.

Figures 7-9 show wetlands typical of those invaded sampled during the survey.

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FIGURES

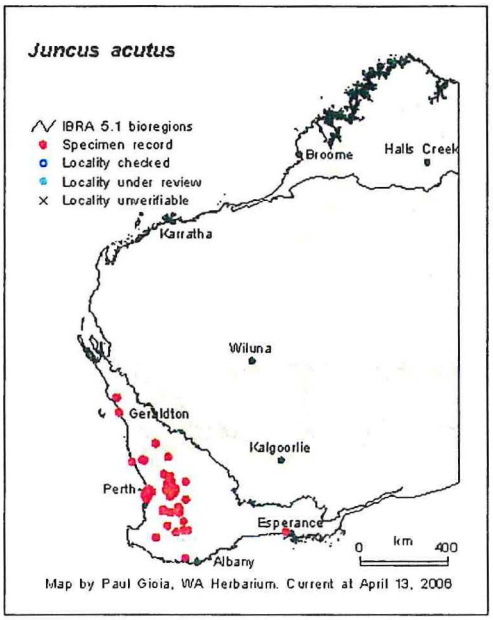

Figure 1. Map showing distribution of *_Juncus acutus_. Mapping by Paul Gioia. Image used with the permission of the Western Australian Herbarium, Department of Environment and Conservation. (http://florabase.calm.wa.gov.au/help/copyright). Accessed on April 13, 2006.

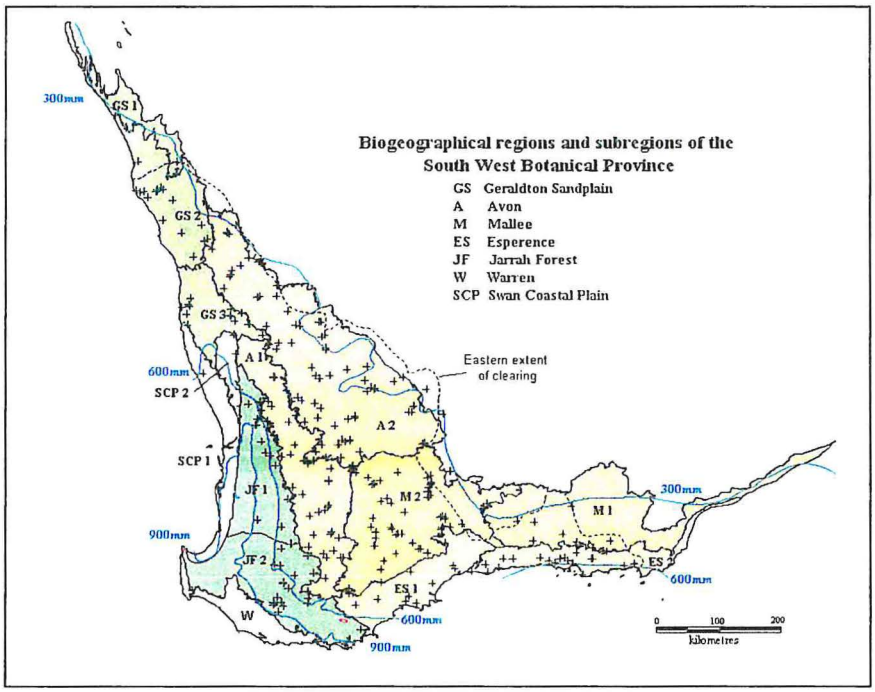

Figure 2. Map showing the location of wetlands sampled during the biodiversity survey of the SW agricultural zone (see Lyons *et al.* 2004). Wetlands are marked with +. Biogeographical regions and subregions of the South West Botanical Province are also shown.

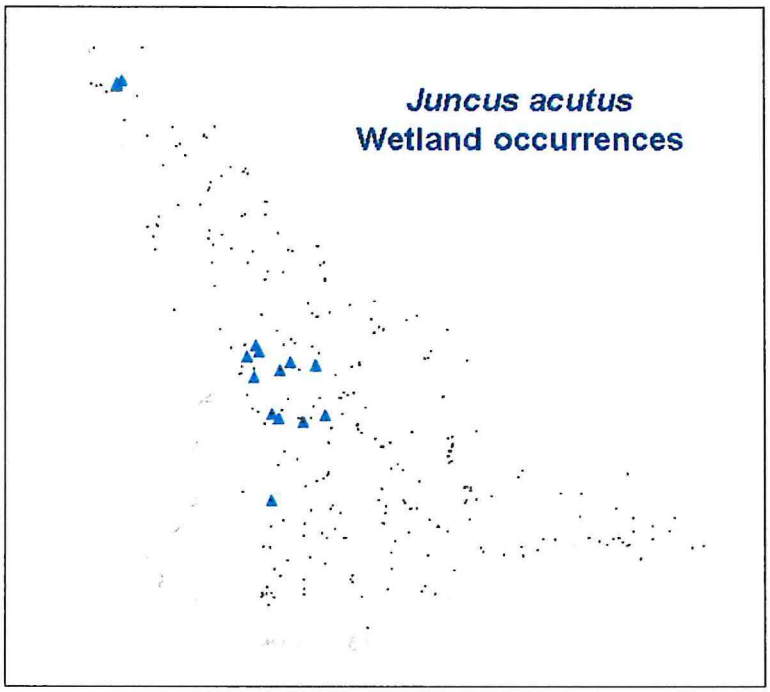

Figure 3. Map showing the distribution of occurrences of **J. acutus* **at wetlands sampled during the survey of the SW agricultural zone.**

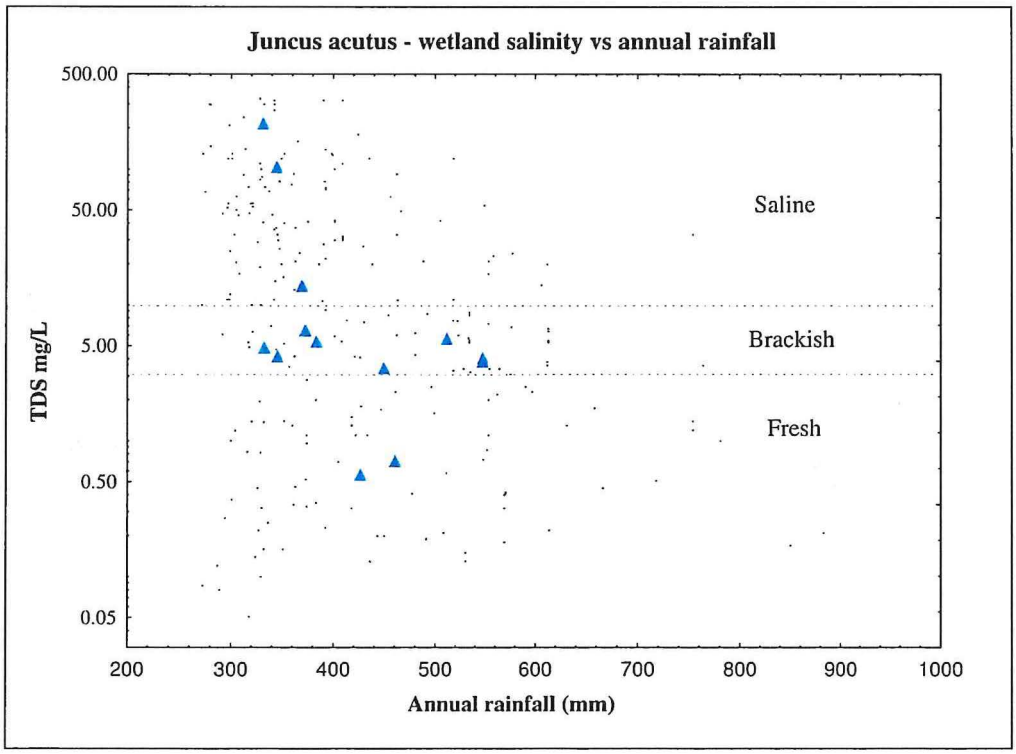

Figure 4. Salinity (water body) of all wetlands (small dots) plotted against annual rainfall. Wetlands at which **J. acutus* **occurred are shown as solid triangles.**

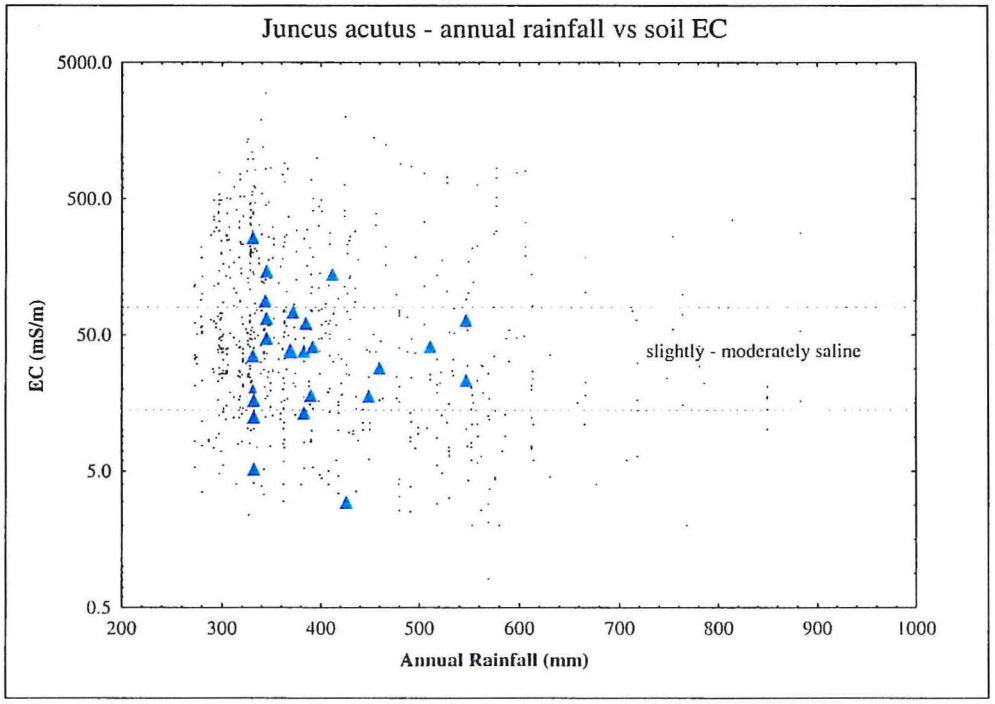

Figure 5. Plot of substrate EC against annual rainfall for all quadrats from the survey (small dots) and occurrence of **Juncus acutus* (solid triangles).

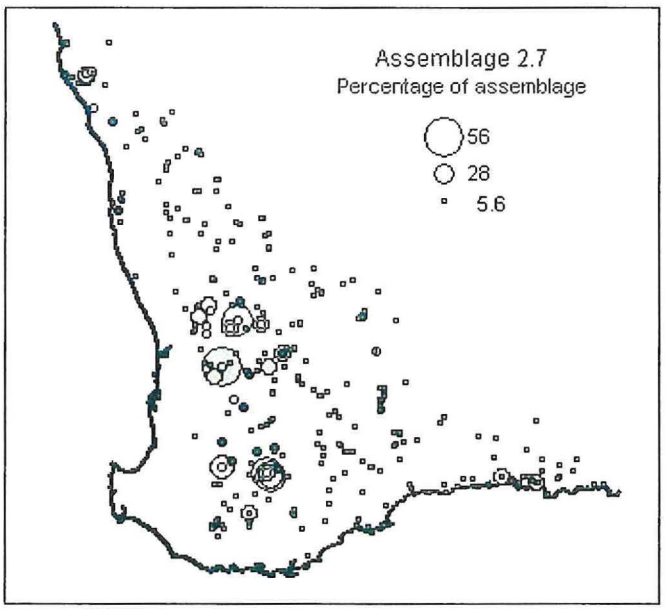

Figure 6. The richness of species assemblage 2.7 at quadrats.

Figure 7. *_Juncus acutus_ invading Eadine Spring, a disturbed freshwater seep near Clackline. Photograph - Michael Lyons.

Figure 8. *_Juncus acutus_ at Clarke's Lake, a large sandplain sump in cleared farmland south-west of Goomalling. Photograph: Michael Lyons.

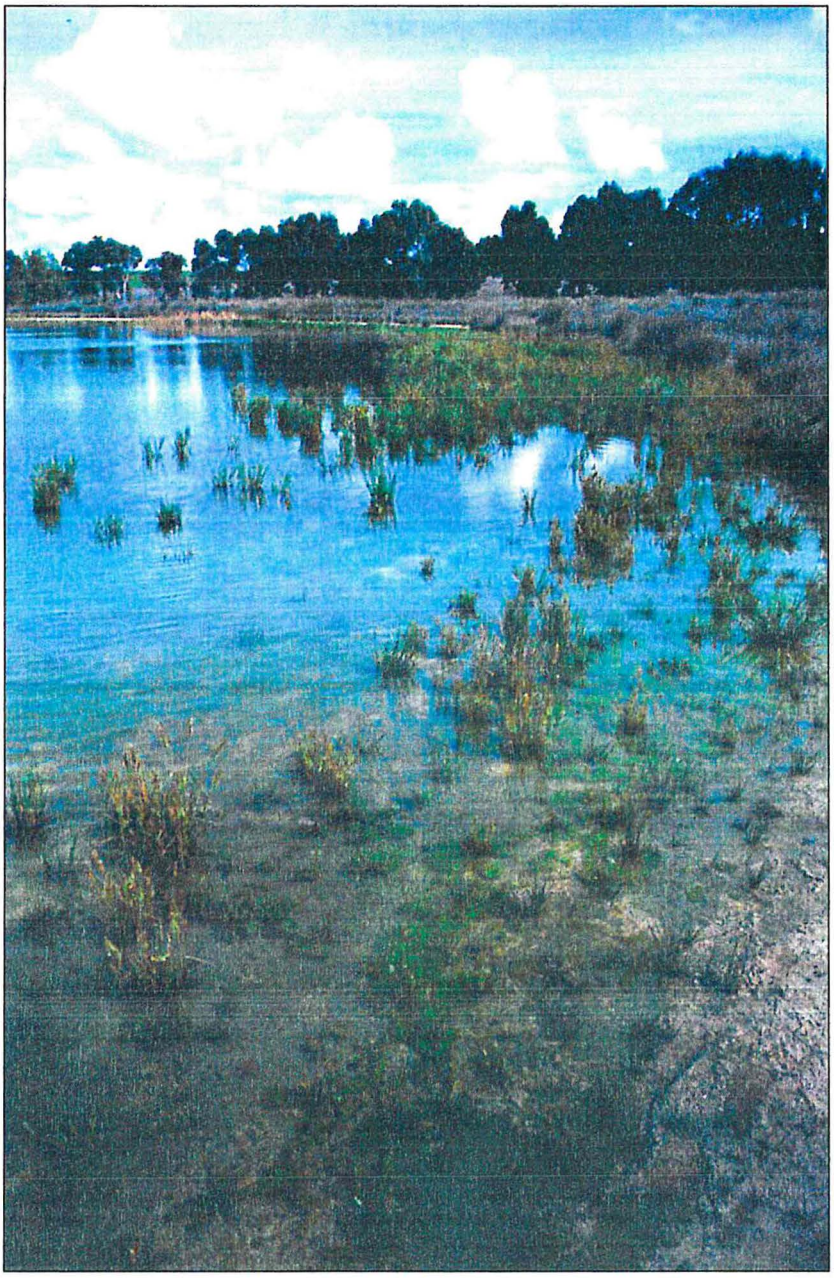

Figure 9. *_Juncus acutus_ forming a large dense zone around Masters' Fresh Lake in sandplain near Tammin. Photograph: Michael Lyons.

Current status and potential spread of **Juncus acutus*

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SUMMARY

**Juncus acutus* is a widespread weed of southern Australia, especially in wet, brackish or saline environments. In Western Australia it has invaded most secondarily-salinated areas in the Agriculture Zone. Outside this zone, it is invading largely intact naturally saline habitats, where it may cause serious impacts both for biodiversity and amenity.

Currently, long distance spread has been largely via misidentified plantings, but anecdotal evidence shows that car tyres are local agents. The species has not reached its potential range and efforts should concentrate on the identification and eradication of populations outside the Agricultural Zone and outlying populations within the Zone.

INTRODUCTION

As noted in the previous paper on the genus *Juncus* in Western Australia (Keighery and Keighery, this publication), *Juncus acutus* is the type species of the genus and of the section *Juncus*. Only one native rush, *Juncus kraussii* subsp. *australiensis* is in this section.

Snogerup (1993) recognised nine species with seven subspecies in the group in the section *Juncus*. Collections of *Juncus acutus* were divided into two geographically separated subspecies (Figures 1 and 2). *Juncus acutus* subsp. *acutus* is found in Western Europe, around the Mediterranean (Figure 3), through Jordan to Iraq and the Persian Gulf, then north-east to the Black and Caspian Seas (Figure 1). *J. acutus* subsp. *leopoldii* is found on many Atlantic oceanic islands, the Americas (Figure 4) and in southern Africa (Figure 2).

Both subspecies are recorded as weeds. Snogerup (1993) considers that populations of **J. acutus* subsp. *leopoldii* have been introduced to Western Europe and have hybridised with the native subspecies *acutus* (Figure 1 and 2). Parsons and Cuthbertson (1992) listed **Juncus acutus* as a weed in Argentina, but only the subspecies *leopoldii* is recorded there by Snogerup (1993) and Kirscher (2002) (see Figures 1 and 2) and that subspecies is native to Argentina. The same appears true for records from South Africa.

**Juncus acutus* subsp. *acutus* is recorded as a weed in Hawaii, on the islands of Hawaii, Kauai, Oahu, Molokai and Maui, in wet sites, bogs and marshy areas (Wagner *et al.* 1999), which is not shown on either original map. It is also recorded as a weed in New Zealand on saline mud flats (Owen 1996) and Australia.

**JUNCUS ACUTUS* IN AUSTRALIA

Juncus acutus occurs naturally on the coast in sand dunes, saline marshes and, rarely, fresh marshes (Figures 3 and 4). Similar habitats, both coastal and inland, have been invaded in Australia. Although past treatments of the species (Parsons and Cuthbertson 1992, Auld and Medd 1987) largely consider this a wasteland or agricultural weed, current evidence indicates that it is becoming a serious environmental issue.

**Juncus acutus* is widespread in southern Australia (see map in Figure 5). However this map does not reflect its reported distribution. It is present in all states and the Northern Territory, despite there being no Queensland records on this map. Morton (2006) records at least three populations (Bribie Island, near Girraween National Park and Moreton Pastoral District) from that State. The first two are currently being subject to active control aimed at eradication.

The occurrence in the Northern Territory is significant as it is listed as a serious threat to arid wetlands in the Northern Territory. Populations have spread along the Finke River between Ormiston and Finke Gorge, despite control efforts (Duguid *et al.* 2003).

In New South Wales **J. acutus* is listed as a general threat to both the coastal marshes and associated threatened communities, for example the coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions (National Parks and Wildlife Service 2006a). Within this habitat it is also considered a threat to the:

- endangered taxa, *Wilsonia rotundifolia* and *Distichilis distichophylla;* and
- vulnerable taxa, *Halosarcia* subsp. *pergranulata* and *Wilsonia backhousei* (National Parks and Wildlife Service 2006b).

In Victoria **J. acutus* is a declared schedule 2 or 3 weed through much of the State (Department of Primary Industries, Victoria 2006). The species is considered a very serious threat to lowland grasslands, grassy woodlands, riparian vegetation, seasonal freshwater wetlands, saline and sub-saline wetlands (Carr *et al.* 1992).

In South Australia the species is invading the internationally significant Coorong wetlands (Brandle 2002, Department of Environment and Heritage 2003).

**JUNCUS ACUTUS* IN WESTERN AUSTRALIA

Current Range

**Juncus acutus* is recorded from north of Geraldton to Esperance in Western Australia. The first recorded collection dates from 1957, but the species must have been introduced much earlier than this date, although Gardner (1930) does not list the species in his checklist of WA's flora. Owen (1996) notes that the species was first recorded in New Zealand in 1923. Interestingly, the species is mentioned in Bentham (1878, page 181):

> "In herb. F. Mueller are two imperfect collections of the northern J, acutus, labelled as from Sieber's Australian herbarium, but probably by some error. They have not Sieber's printed labels, and no other specimens from the southern hemisphere are known."

If these were from Australia, then introduction to Victoria must have occurred in the nineteenth century and into Western Australia between 1920 and 1950.

**J. acutus* is most widely established in the Agricultural Zone, as detailed by Lyons (this publication), where it is largely a weed of perennial wet sites, usually those affected by secondary salination. This is true for most of the occurrences in reserves in this area (e.g. Chilimony, Martinjinni and Badjaling in Table 1).

Currently, outside the Agricultural Zone **J. acutus* is present as small populations, usually along road verges, drains or as deliberate plantings. As noted in several papers and in the discussion, most of the spread of **J. acutus* is by intentional accidental human spread, largely by the planting of this species instead of native rushes such as *Juncus pallidus*. This has enabled the species to invade south of Perth into the Mandurah and Dunsborough area (Clarke 2007). The occurrence of small isolated stands of **J. acutus* along major roads suggests that the small seeds are carried in mud and the large sharp capsules may adhere to tyres.

It is also invading several conservation wetlands of high biodiversity and recreational significance. **J. acutus* is currently spreading onto the Swan Coastal Plain, being recorded in the Beeliar Regional Park, the Rockingham Lakes Regional Park and around the Swan River Estuary (Table 1).

Potential range and effects

There seems little doubt that **Juncus acutus* could invade many of the Ramsar wetlands of south Western Australia, most coastal estuarine systems, several Threatened Ecological Communities and other sites of significance (Table 2). **J. acutus* is favoured by both disturbance and eutrophication which are increasing in many wetlands as population growth increases in and adjacent to most of these habitats.

In such areas it could displace the native *Juncus kraussii* (which provides foreshore stability and faunal habitats) both by direct competition and by hybridisation. Hybrids between **J. acutus* and related native species *Juncus kraussii* have been recorded at Lake Coogee (Figure 6) in the Beeliar Regional Park.

With its long needle sharp leaves, **J. acutus* is a very unpleasant plant to walk through, or fall into. Along the Swan River and Mandurah Estuary it will greatly affect recreational usage and potentially cause severe eye injuries to children.

While a prediction map of the potential range for **J. acutus* was prepared by the Weeds CRC (Figure 7), we feel that the actual distribution map of the related native *Juncus kraussii* (Figure 8) is a more accurate guide to the potential range of this weed (Figure 9).

With the described impacts and potential distribution, it is very evident that control of this species is urgent. Control should focus on the eradication of the generally small, isolated populations outside the Agricultural Zone and the isolated populations within the Zone. To limit the further spread of the species, soil should not be moved from infected areas and particular care should be taken when sourcing *Juncus* seed for revegetation. As native *Juncus* species such as *J. pallidus* spread naturally relatively quickly from area to area and clump to clump, more reliance should be placed on natural revegetation.

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ACKNOWLEDGEMENTS

Thanks to Kate Brown who alerted us to the existence of the hybrids at Lake Coogee.

TABLES

Table 1. Occurrence of **Juncus acutus* in Conservation Reserves.

Agricultural Zone
Chilimony Nature Reserve
Martinjinni Nature Reserve
Wambyn Nature Reserve
Badjaling Nature Reserve
Toolibin Nature Reserve
Taarblin Lake Nature Reserve
Swan Coastal Plain
Beeliar Regional Park (Lakes Coogee, Market Garden Swamp)
Rockingham Lakes Regional Park (Lake Walyungup)

Table 2. Conservation areas/ecosystems threatened by **Juncus acutus*.

Key

* **Juncus acutus* already present in this area

	Ramsar Wetlands
*	Peel/Harvey
*	Vasse/Wonnerup
	Esperance Lakes
	West Coast Estuarine Systems
	Hutt Lagoon
	Greenough estuary
	Moore River Estuary
*	Swan River Estuary
	Leschenault Estuary
	South Coast Systems
	Hardy Inlet
	Wilson Inlet
	Princess Royal Harbour
	Culham Inlet
	Stokes Inlet
	Threatened Ecological Communities
	Lake Thetis Thrombolites
	Lake Richmond Thrombolites
	Lake Clifton Thrombolites
	Sedgelands in Holocene dune swales(Community 19)
	Other
*	Hutt River/ Yallabatharra Springs
*	Coastal lakes and seeps of Mount Lesueur
	Rottnest Island lakes and wetlands
*	Lake Gore system
*	Braided saline drainage systems (Buntine Marchagee Recovery Catchment)

FIGURES

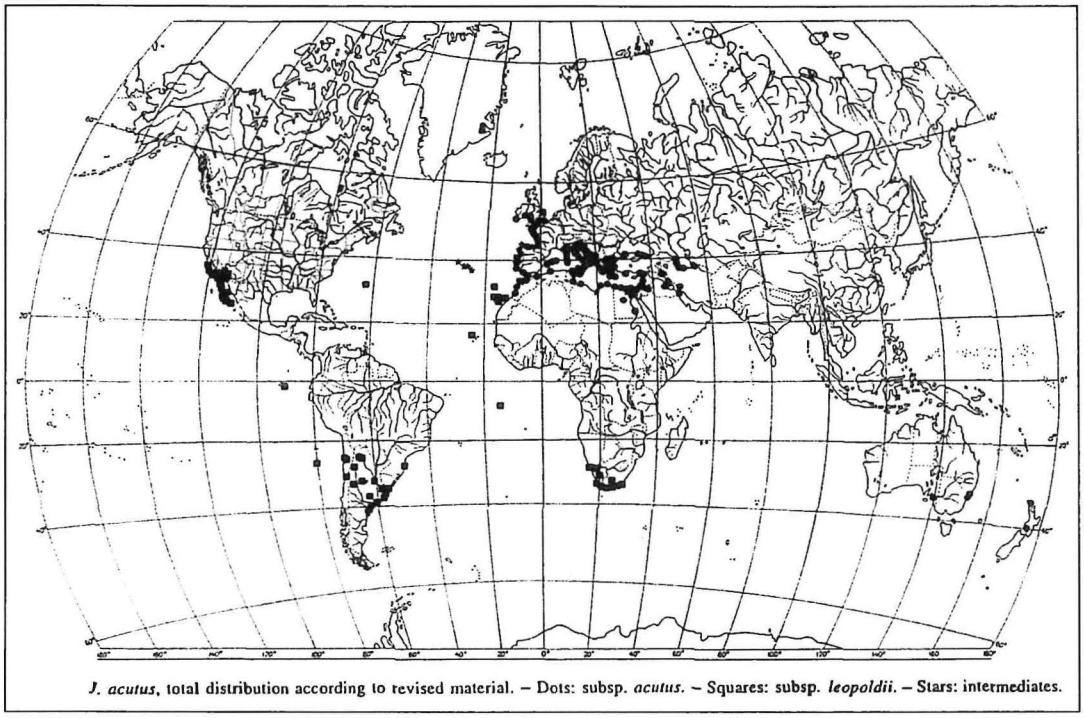

Figure 1. Distribution map of native and weed *Juncus acutus* from Snogerup (1993).

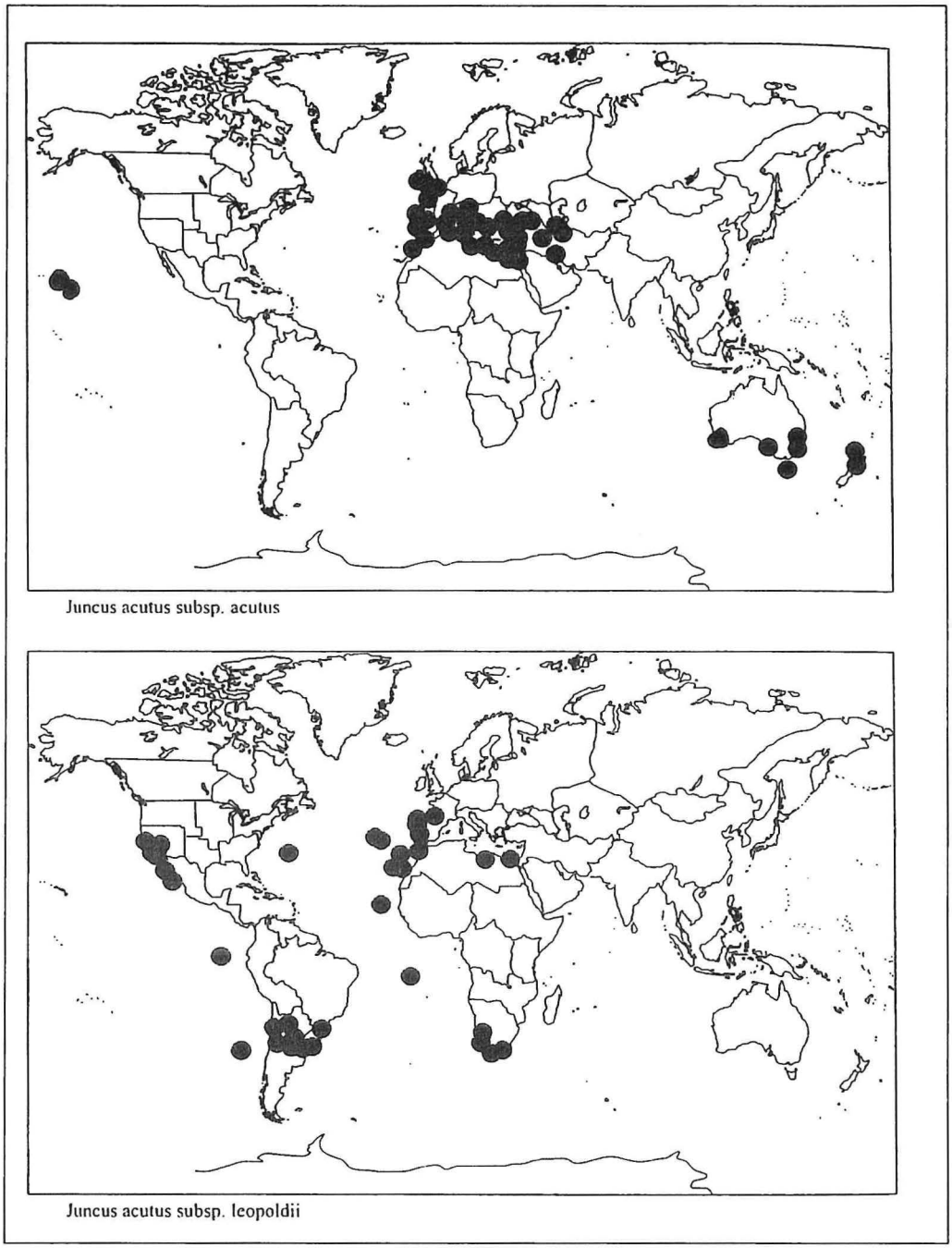

Figure 2. Distribution map of native and weed *Juncus acutus* from Kirscher (2002). Note that we have added South-West Australia and Hawaii to the distribution. The intermediates (hybrids) between the two subspecies in Europe are not differentiated in these maps.

Figure 3. *Juncus acutus* subsp. *acutus* in the Camargue, southern France. Photograph - Michael Lyons.

Figure 4. *Juncus acutus* subsp. *leopoldii* on Santa Catalina Island, California. Photograph - Greg Keighery.

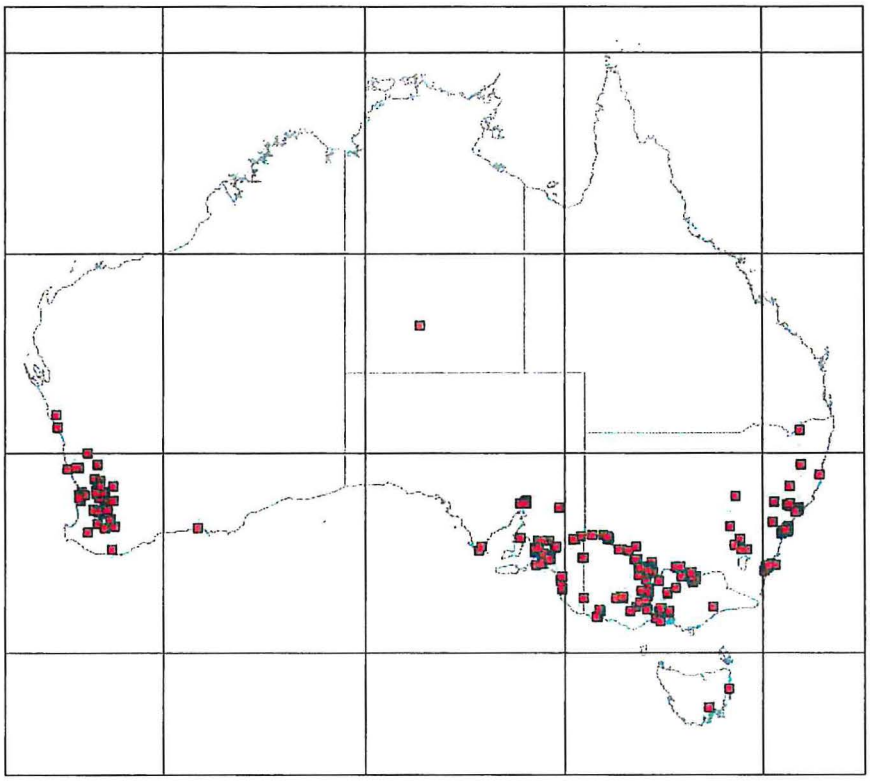

Figure 5. Distribution of *_Juncus acutus_ in Australia from Australia's Virtual Herbarium (2006).

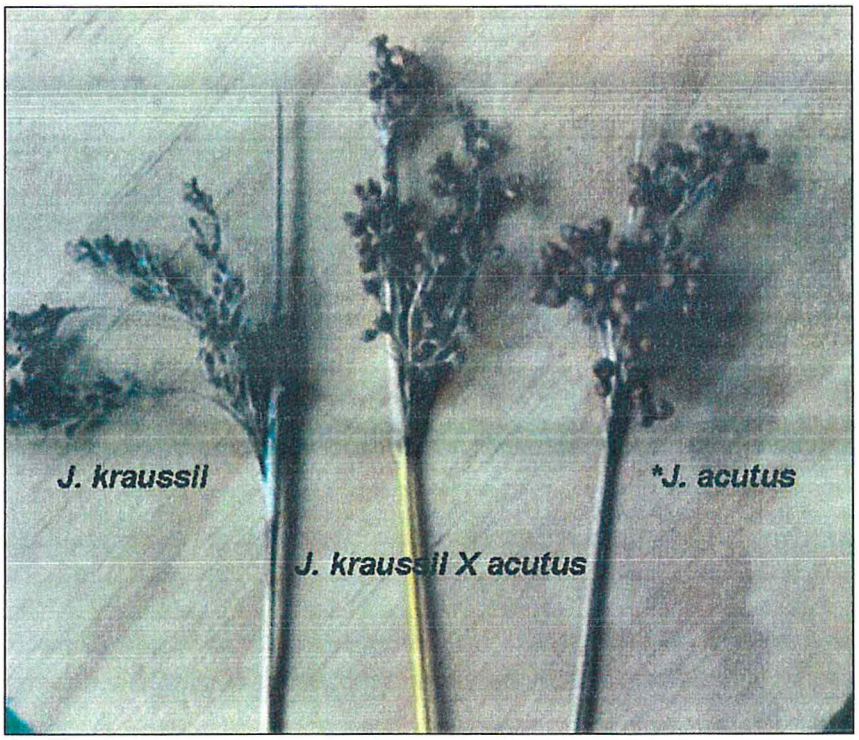

Figure 6. From left to right, _Juncus kraussii,_ putative hybrid _(J. kraussii X acutus)_ and *_J. acutus_ from Lake Coogee. Photograph - Bronwen Keighery.

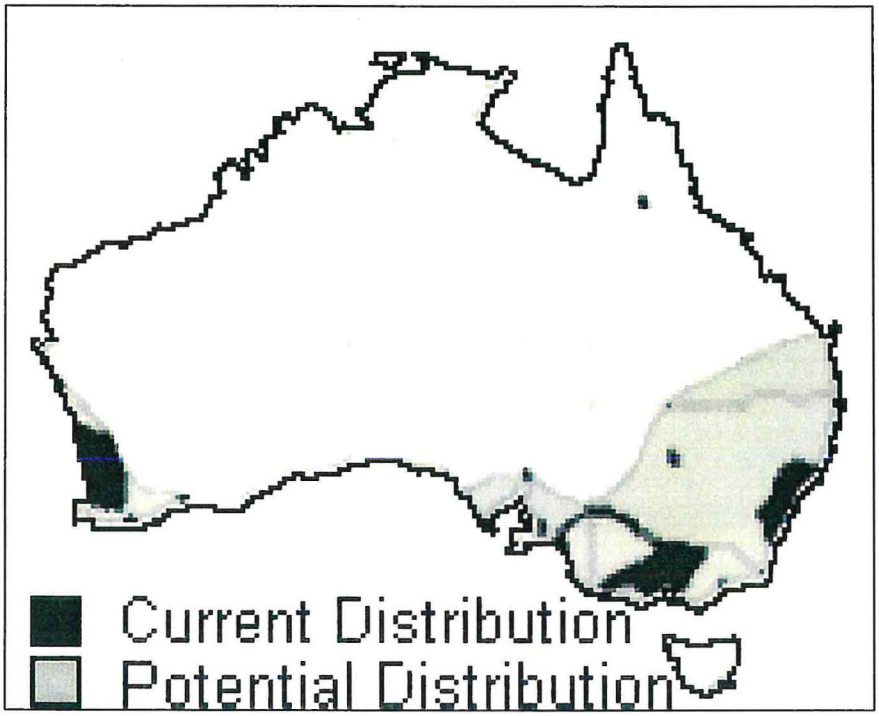

Figure 7. *_Juncus acutus_ prediction map (Australian Weeds Committee 2006)

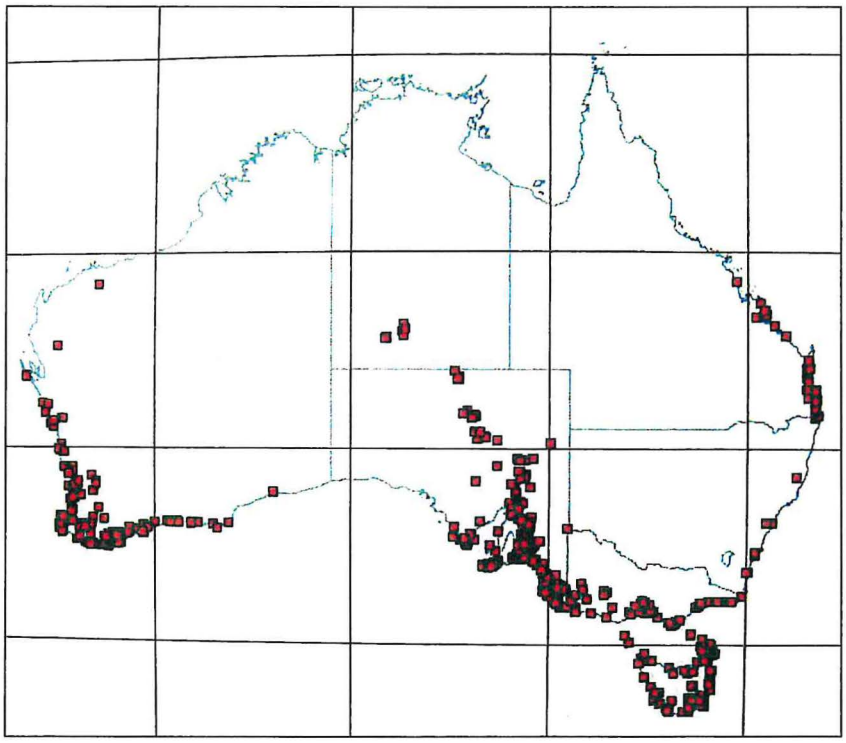

Figure 8. Distribution of *Juncus kraussii* in Australia from Australia's Virtual Herbarium (2006).

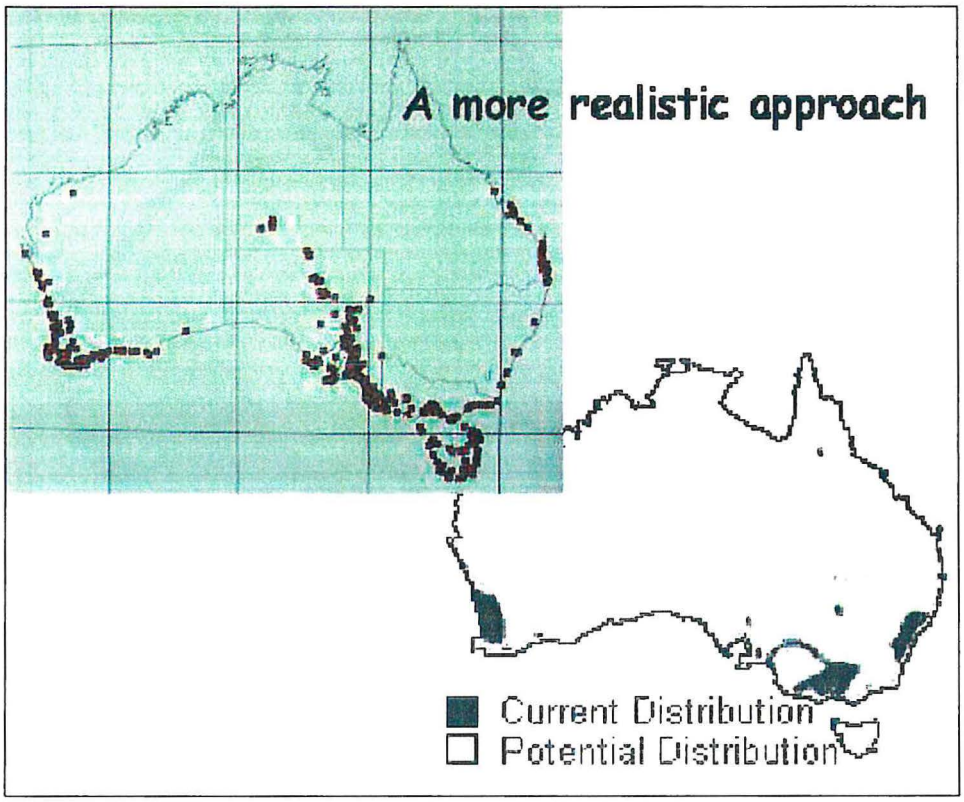

Figure 9. It is predicted that the range of **Juncus acutus* will, more realistically, approximate that of *J. kraussii*.

Biology of Sharp Rush, **Juncus acutus*

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BIOLOGY OF SHARP RUSH, **JUNCUS ACUTUS*

Sharp Rush, **Juncus acutus*, is an erect, very spiny plant that forms a perennial tussock up to 2 metres high. It reproduces from seeds and rhizomes. The stems and leaves of **J. acutus* are filled with continuous pith.

The natural distribution of Sharp Rush includes the continents of Africa, Asia, Europe and North America. It has been introduced to New Zealand, South America and Australia.

In Western Australia, Sharp Rush invades saline or brackish to freshwater wetlands on calcareous soils from Geraldton to Esperance (see Figures 1, 2 and 3).

The flowers of Sharp Rush are small, green to brown, occur near the tops of the stems and appear mainly during spring and summer. New plants do not flower until they are at least two years old, by which time perennial crown and rhizomes have developed.

Stems of Sharp Rush are numerous, erect, cylindrical, up to 4 mm in diameter, smooth, dark-green and pithy, 1 to 2 metres high and they taper to a sharp point. The leaves are similar to the stems but without flower heads and tipped by a very sharp spine. New leaves and stems are continually produced as old ones die, although most new growth occurs during spring. Roots form a thick fibrous mat with short rhizomes. Plants are long-lived and can establish vegetatively from pieces of old crown following cultivation or mechanical disturbance.

Spread is mostly by seed, which germinates at almost any time of the year. Water and wind are the main dispersal agents, however farm machinery, vehicles, stock and hay will also spread seed. Each seed capsule or fruit can hold up to 200 seeds and each plant produce up to 4000 seeds. The seed has high rates of germination (75%) and may persist for many years in the soil. Availability of light is a major limiting factor for germination, so wet, sandy, open substrates are favoured sites for establishment of new populations.

IMPACTS OF SHARP RUSH ON NATIVE VEGETATION

Observations suggest Sharp Rush significantly reduces native species richness in the wetland plant communities it invades. Over time, it forms dense monocultures, displacing and inhibiting recruitment of native sedges, herbs and shrubs.

FIRE AND SHARP RUSH MANAGEMENT

Fire creates optimal conditions (abundant light and open bare ground) for germination of seed and establishment of new populations. Many adult plants will also resprout following fire. So the season following a fire event is an optimal time for herbicide control of populations. The cover of native vegetation is reduced, resprouting adult plants are highly susceptible to herbicide treatments and seedlings are highly visible in the post-fire landscape.

Fire may also be a useful tool for assisting regeneration of the native plant community after Sharp Rush has been killed with herbicides. Herbicide control of large, dense infestations can leave significant biomass that prevents regeneration of the native plant community and creates high fuel loads. Carefully controlled burning of the biomass would reduce the fuel loads and may also promote regeneration of the native plant community. However, fire may also facilitate invasion of other weed species and intensive management may be required in the following months and years.

MANAGEMENT IMPLICATIONS

Sharp Rush appears to have the capacity to invade intact wetlands of calcareous soils on the Swan Coastal Plain and displace native plant communities.

Open damp areas on calcareous soils are favorable for seed germination and so particularly susceptible to invasion.

Late spring following the flush of new growth is the best time for control. In wetter areas, where there is substantial standing water, this may not be possible.

Seed may persist in the soil for a number of years and control strategies should take this into account.

Following fire is an optimal time to control populations.

Fire could be a useful tool for restoring invaded native plant communities following herbicide control of Sharp Rush.

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FIGURES

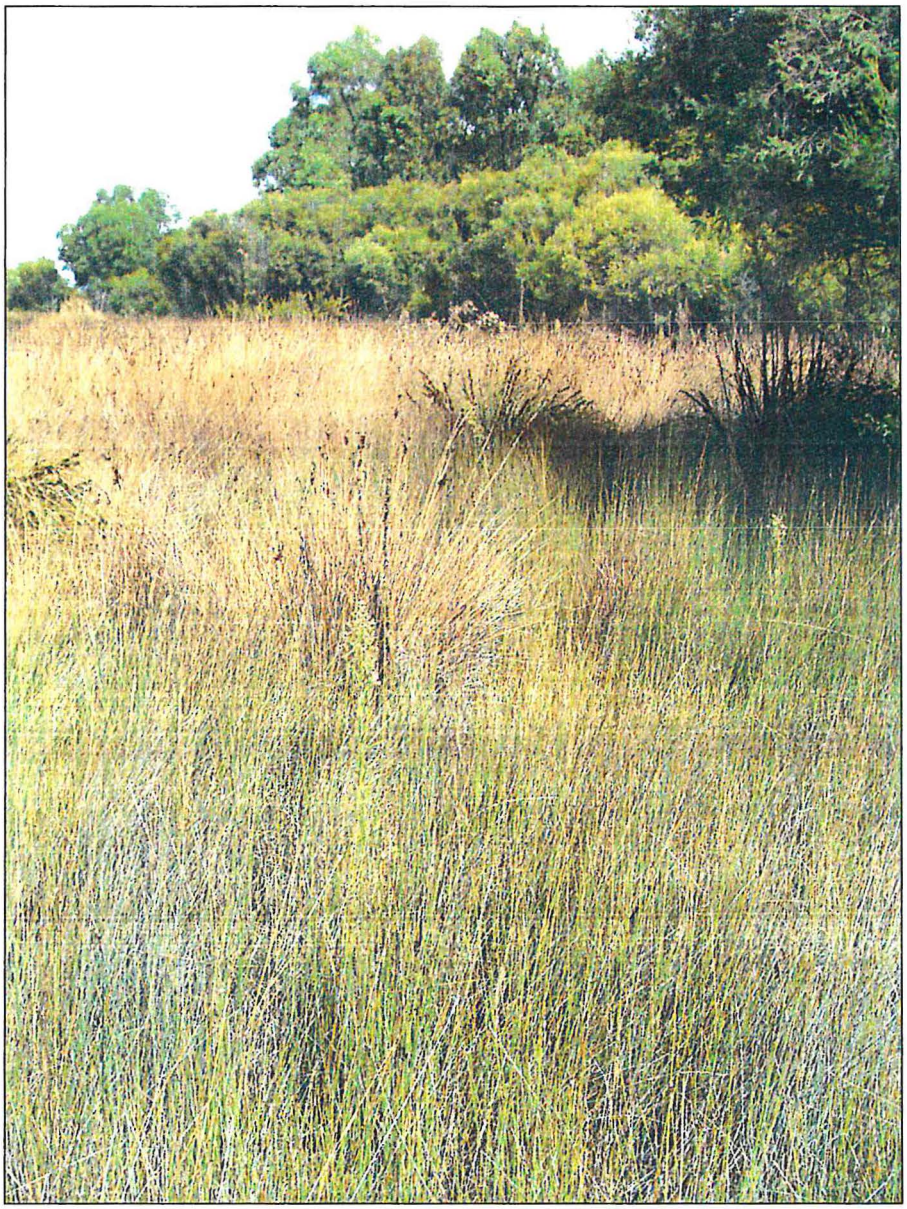

Figure 1. Recently sprayed Sharp Rush where it has invaded the fringing vegetation and started to displace the native Bare Twig Rush (*Baumea juncea*) sedgeland, Lake Cooloongup in the Rockingham Lakes Regional Park. Photograph - Kate Brown.

Figure 2. Sharp Rush populations establishing around the edge of Lake Walyungup, Rockingham Lakes Regional Park. Naturally open calcareous lake beds seem particularly susceptible to invasion. With no competition from native perennial vegetation Sharp Rush seed are able to germinate and new populations establish. Photograph - Kate Brown.

Figure 3. Sharp Rush invading the low lying flats of Market Garden Swamp, Beeliar Regional Park, displacing native samphires, sedges and grasses. Photograph - Kate Brown.

Control of Sharp Rush, **Juncus acutus*

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INTRODUCTION

**Juncus acutus,* Sharp Rush or Spiny Rush, is a rapidly spreading plant in Western Australian wetlands, river systems and agricultural areas including creeks and seepage areas. Sharp Rush is a major weed in other Australian states and in New Zealand.

In order to control this weed, we need to find out more about its biology. For example, weeds are much easier to control when they are actively growing, so it would help to know their time of growth flush. Their food reserves are lower when they are flowering as their whole system is working overtime to produce enough energy for seed production and subsequent growth, so this is often a better time to spray. Further questions remain to be answered. Can we control the weeds before they set seed? Is there a herbicide which will also reduce the viability of the seed before it is mature, thereby reducing the soil seedbank? In the case of **J. acutus*, its seed is highly viable with 85 per cent capable of germinating in 5 days (Miller pers. comm.). How long does the seedbank last? Is it preferable to clear the area to bare ground to stimulate seed germination or to keep the biomass there to reduce light and allow the seed to lose viability and die?

KNOWN METHODS OF CONTROL

The usual method of control in natural ecosystems is spot spraying with glyphosate; in non-crop and degraded situations such as open paddocks in Victoria, the use of hexazinone (Velpar L®) at a rate of 360-540 ml/100 L water is permitted (Anderson *et al.*) but care must be taken to check local regulations because restrictions apply in chemical control areas. This is not a method I would recommend here, however it gives excellent control of mature plants and will kill seedling recruits for up to 6 months.

Rates of glyphosate 360 quoted from different sources, expressed in different ways, vary from 1 to 1.5 per cent, 6 L/ha, 10 ml per litre water, one in 50 parts of water to one in 75. After the plants have died, some people recommend the use of fire to reduce the biomass, but care must be taken to ensure the plants are really dead before burning otherwise they can resprout.

Fire also opens up the area, creating bare ground; this favours the recruitment of seedlings since seeds require light to germinate. This also applies to native *Juncus* species (Merritt pers. comm.) so if indigenous species are present fire will also stimulate their seedbank to germinate. It is important when restoring an area to stimulate the germination of **J. acutus* in order to maximise the removal of germinants in one go and to more easily target them. Fire could also substantially reduce the seedbank of **Juncus acutus* by burning the seed lodged amongst the above ground biomass and some of the seed lying on the soil surface. Slashing the tops will also allow the plants to put on new growth which will be easier to target and may give better kill rates when sprayed.

Some new control methods have been investigated (Paul and Young 2005) during an intensive 30 month study programme focusing on 'reducing the use of herbicides' in the artificially created Badu Saltmarsh at Sydney Olympic Park. The study included the use of cutting and painting with

glyphosate, spraying glyphosate, the use of mulch to reduce seedling recruitment, the application of salt to cut stems and digging out (scraping) the plants by machine. In this case the 'preferred recommendation' was scraping and replanting with native saltmarsh species although mulching with *Juncus* tops, minus any seed, and replanting may give better long term results. They only recommended the use of glyphosate as a last resort despite the excellent results from one spray application (glyphosate 360 one part to 50 parts water) which killed most of the plants it was applied to.

Local experience indicates glyphosate is basically the only herbicide used to control **Juncus acutus*. Control has not been practiced for many years, and little research appears to have been done on control methods for this species as it is regarded as a 'fairly new weed' to land managers. The most common rate used is 1 per cent glyphosate and it is applied at any time of the year when plants can be targeted, that is, when it is dry enough to get access into infected areas (usually late spring to late autumn). Kill rates vary considerably; this often depends on the size of the plants (younger plants are easier to target and get good coverage) and penetration into the centre of the plant.

Better results are claimed using a mixture of glyphosate and Brushoff® metsulfuron methyl (Bright pers. comm.). Glyphosate alone did not kill many plants, however glyphosate 2 per cent concentration mixed with Brushoff® 5 g in 200 L, with the addition of Pulse® 2 ml/L, gave excellent results. This mixture killed 100 per cent of small plants and most of the large plants but there was some respraying of older plants after resprouting. *Baumea juncea* was also affected when sprayed with Brushoff® alone to control *Pelagonium capitatum* in some trial plots, killing up to 50 per cent. Note there is no 'label information' suggesting metsulfuron methyl is active on *Juncus* species, and information from technical advisors employed by manufacturers or vendors of this product does not describe it as being effective on *Juncus* species. This kill rate may be a 'one off' (Moore pers. comm.) as we have never recorded metsulfuron methyl killing *Juncus* species. Perhaps the timing of spraying was better than normal since different levels of wax are produced on this species during the growth cycle; good timing could result in better penetration as glyphosate is regarded as being very good at killing *Juncus* species. Spraying can be done at any time of the year but it is best to wait until the area has dried out and there is no remaining free water. Spraying can be part of a routine weed programme, that is, many weed species can be sprayed in the same operation.

Herbicide trials (by Kate Brown and Bob Dixon) using different rates of 2,2-DPA Propon® and glyphosate at this stage have not been fully evaluated, however early indications are that glyphosate gives better kill rates, and careful spraying can avoid too much off-target damage to indigenous species.

Manufacturers' recommendations must be followed when applying herbicides; try to avoid using any herbicide over free water (with **J. acutus* it is possible in many cases to wait until early summer or later, depending on rainfall events, when the area has dried out); don't spray when it is raining; spray early in the day during hot weather; avoid spraying in windy conditions; don't spray when plants are dormant or under stress, e.g. drought or frost conditions. Where possible, seek appropriate advice and make sure you get the required authority's permission for spraying. Always try to use the most environmentally friendly methods.

Sharp Rush is difficult to wet as the above ground parts (stems) are narrow and shiny. A penetrant such as Pulse® (organosilicones) may provide better coverage and penetration of the herbicide rather than an ordinary wetting agent.

The use of ammonium sulphate, $(NH_4)_2SO_4$, with glyphosate is often recommended. Ammonium sulphate has several actions: it etches the leaf surface, allowing greater penetration of the herbicide; it reduces antagonism of glyphosate with hard water; it changes the way glyphosate crystals form on the leaf and improves absorption (Moore and Moore 2005). Note the use of ammonium sulphate may not be appropriate in some wetland situations due to 'unknown' side effects, e.g. adding extra nutrients to the system.

PRESENT RECOMMENDATIONS FOR CONTROL OF *JUNCUS ACUTUS*

When using herbicides, it is important to adhere to any regulations or conditions that may apply, e.g. by using chemicals approved by the Agricultural Pesticides and Veterinary Medicines Authority (APVMA) so as not to affect aquatic and marine life. All your equipment and that of any contractors must be clean before starting any operations, i.e. free of dirt or weeds, and tanks or spray lines must be decontaminated and flushed before use.

Tackle new populations first to stop populations spreading as this is more cost effective; when resources are available tackle larger populations. Note that small populations may be removed by hand, for example with a mattock, but this needs to be done during the dry season. Make sure you take the plants off–site, otherwise they may re-root. If you have the resources and it's still wet, it may pay to remove the tops to reduce the seed load falling to the ground. Always bag seed heads, take off site and destroy, for example by burning or deep burial.

The usual control method would be to spot spray with glyphosate 360 at a rate of 20 ml glyphosate 360 to one litre of water, plus the addition of a penetrant, e.g. Pulse® at 2 ml/L water. Avoid spraying over free water. Where appropriate, supplement regular glyphosate with APVMA approved formulations such as Raze® and Roundup Biactive®. Arrange for follow up spraying to control missed plants and new seedlings. Monitor the area on a regular basis; it will take several years to eradicate populations. Replant, where necessary, to stop other weeds and more *Juncus* filling in the gaps but ensure that the right species are planted back. If necessary, control plants upstream as more seed will wash down, and cooperate with neighbours to control plants on their land. Control in completely degraded areas such as paddocks, or other sources that could spread seed into your wetland, could be done with boom spraying equipment to reduce costs; it may be necessary to plan for erosion control in these areas. Make provision for unplanned fires. If a fire occurs make sure you are able to use your present resources in this area and delay your planned programmes, if appropriate, to the following year, or seek further special funding. If you decide to burn an area before or after spraying make sure you have permission to do so and take the necessary precautions to prevent wildfires.

Make sure everything you do is documented, e.g. known and new populations; keep staff or contractors and, where appropriate, neighbours informed; record what control methods were used 'where and when'; record the results; network with other land managers to find out how their control programmes are going.

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PERSONAL COMMUNICATIONS

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Swan River Foreshore Assessment

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The Swan River Trust, in conjunction with the Swan Catchment Council, is undertaking a Foreshore Assessment project to prepare report cards on the condition of, and pressures on, the Swan and Canning Rivers. The project area extends from the Fremantle Traffic Bridge to Moondyne Brook on the Avon River, the diversion dam on the Helena River, and Stinton Creek on the Canning River.

One section of the survey includes recording invasive weed species, including **Juncus acutus*, throughout this area. Figure 1 shows the current scattered stands of this weed in the study area.

FIGURE

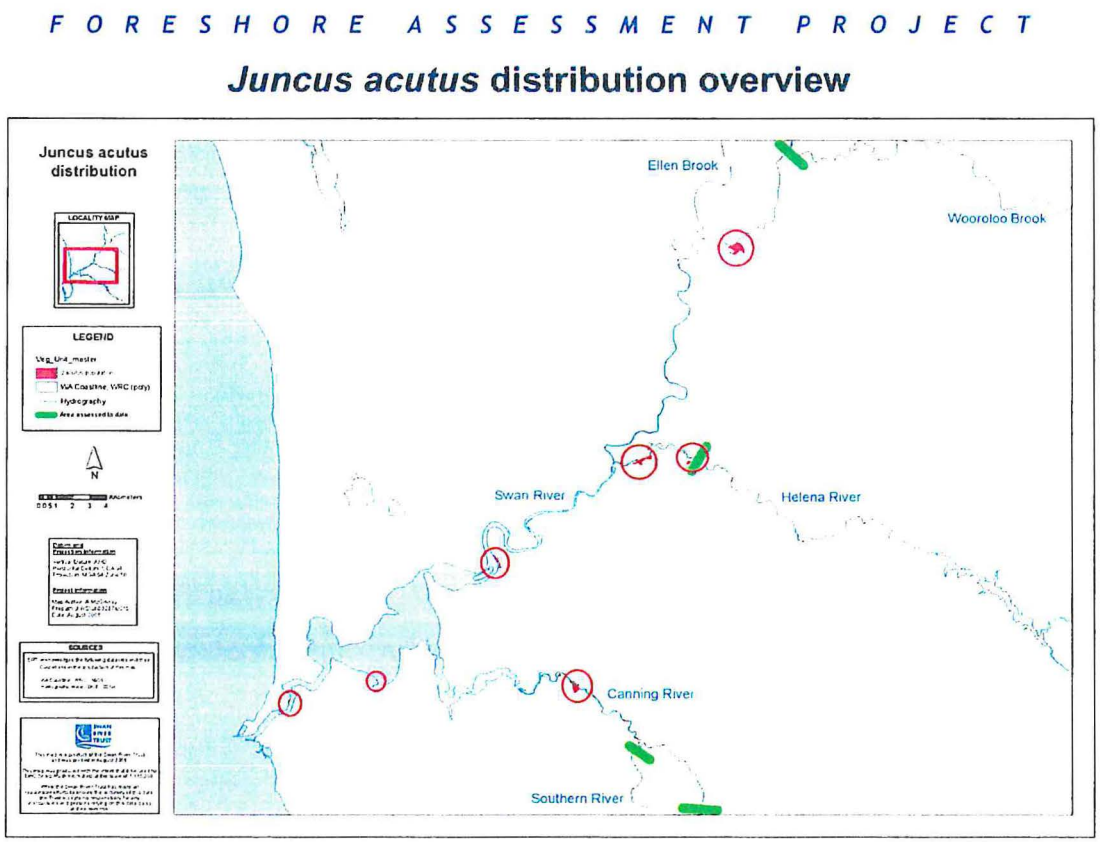

Figure 1. Known distribution of **Juncus acutus* along foreshores, as mapped by the Swan River Trust.

***Juncus acutus masquerading as *J. pallidus*: CRREPA experiences**

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To begin the afternoon I have a story that should raise your awareness of how **Juncus acutus* can sneak into even a highly planned revegetation project and result in significant loss of dollars, time and effort. However, the story does have a happy ending.

To set the scene, the story starts in 1994 when members of the local community in the southern suburb of Rossmoyne became concerned at the management strategies proposed at the time for both the Yagan Wetland Reserve, then known as the Bullcreek Wetlands, and the Rossmoyne/Shelley foreshores of Bullcreek and the Canning River.

The Canning River Residents Environment Protection Association (CRREPA) was formed to provide community consultation into the management process.

In 1994 CRREPA applied for funding to the National Landcare Program (NLP) 1995/96 program for $6080 to assist with its aim to "... revegetate and regenerate the Bullcreek Wetlands and the Lower Canning Foreshore, returning it to somewhere near its original state and to reintroduce local native species which have become endangered or threatened".

Seven separate sites, from the Bullcreek Wetlands, and scattered along the Rossmoyne and Shelley foreshores of the Canning River estuary were proposed. Terry Potter, one of CRREPA's inaugural members, created a series of maps that detailed each site and the proposed layout for the planting of the selected plant species.

The application stated that "This project will enable us to build on our current activities of removing invasive and noxious weeds; collecting and germinating local native seeds for use in regeneration; monitoring the water quality of the Lower Canning River as part of the Ribbons of Blue program; working with the City of Canning, local community groups and relevant Government management bodies; investigating our local natural environment and contributing to its management and encouraging the wider community to participate in the management of their natural environment". The NLP obviously thought that we sounded like a good investment and the $6080 was approved.

Work commenced in 1995 on sites 1 – 6.

This story focuses however on the work carried out in 1996 in site 7, the Bullcreek Wetlands, now known as Yagan Wetland Reserve. Because the Yagan Reserve Management Plan was being drafted by the City of Canning and the final Management Plan would not be implemented by the Council until sometime in mid 1995 planting was delayed until 1996.

In the meantime the funds were used by a commercial plant nursery to germinate and cultivate seed from the Yagan Reserve "...plus other species as listed in the appendix of the draft of the Yagan Wetlands Reserve Management Plan" (application to Lotteries Commission 19/12/95). This is where the opportunity for **J. acutus* arose. We lost control of the provenance of these 'other species'.

Also in December 1995 further funds were sought from the Lottery Commission's Gordon Reid Foundation for Conservation, to "... enable our community group to provide vital *Juncus kraussii* rushes (wetland rushes)...A further benefit from increasing planting of *J. kraussii* to replace the invading *Typha orientalis* in the wetlands is that the nutrient stripping potential will be increased as well as the eradication of the invading exotic typha" (application to Lotteries Commission 19/12/1995). $5000 was gratefully received from Lotteries.

During the summer of 1995-96 ten LEAP (Land Environment Action Program) workers had made a start on cleaning up the exotics and weeds that had invaded the area and together with the plants obtained through the grants there were also 750 trees from seed that CRREPA members had collected, germinated and pricked out with help of the Murdoch Branch of the Wildflower Society and were raised in the City of Canning nursery.

The creek banks had been prepared by the City of Canning using netting and hemp matting to maintain the bank. They also installed a standing pipe to water the plants. We were supplied with rubber boots for any planting that needed to be done by standing in the creek.

In March and April 1996 the call went out to CRREPA members to "Come along to help us restore the Yagan Wetland Reserve back to how it should be and do your little bit to help our planet".

The matting made planting very difficult as a hole through the matting had to be cut first with scissors. However an enthusiastic team successfully planted both banks of the creekline. A lot of preparation had gone into this project.

Imagine the disappointment when **J. acutus* was discovered in August 1997.

What was being admired at the time as excellent growth from the 1996 planting proved to be stands of **J. acutus* coming into flower. The source was traced to the "other species" that had been supplied by the commercial plant nursery. We discovered that seed that had been obtained by the nursery from possibly South Australia was either mis-named or contaminated. Vigorous negotiations by CRREPA's then President, Margot Ross with the nursery involved, failed to obtain a solution that would have urgently removed the plants and would have seen them replaced with more suitable ones.

However, a shining knight in the form of APACE Nursery came to the rescue. They also had been involved in supplying plants for the Yagan Wetland Reserve project; by co-incidence, they had also supplied incorrect seedlings, this time **J. microcephalus,* a native to North and South America and which occurs in disturbed areas. Greg Reid and a team from APACE removed all the suspect plants, both **J. acutus* and **J. microcephalus,* and substantially replanted the site with *J. kraussii.* A truly outstanding commercial commitment to their business's integrity.

It is with much relief that I can report that **J. acutus* was totally eradicated from the Yagan Wetland Reserve. Only two other isolated plants were found this time at Site 5 and these were safely removed.

The CRREPA experience with **J. acutus* could have so easily been far more serious. If the CRREPA team had not queried the unusual plants growing in the site, they would have succeeded in seeding and eradication would have been far more difficult. Also they could potentially have spread along the Canning River estuary and out into the Swan. As it was, a whole growing season was lost and the creek banks suffered two successive years of erosion from the lack of plant cover. Interestingly the hemp matting rotted away during the first year, and who knows what effect its presence had on natural regeneration. Another story waiting to be told.

This was all a long time ago now, and very little was known or if known, available to the fledging 'friends' groups of the time. Certainly the importance of provenance was only appreciated by a few. The interest was in bringing back a 'bush-like' or 'wetland-like' environment rather than restoring a local plant community. One of the very few local research publications available at the time listed **Isolepis*

prolifera, **J. articulatus*, **J. microcephalus* and **Typha orientalis* as wetland plants suitable for revegetation because of their nutrient stripping capabilities. Hopefully this has changed and this story of CRREPA's **J. acutus* experience will become an interesting anecdote in the history of bush regeneration in this State.

Of the seven project sites we were very fortunate that only Yagan Wetland Reserve was infected with **J. acutus*. How much worse it would have been if the whole project stretching along the Bullcreek and Canning River foreshores, had been compromised. As well as the environmental damage it would have affected the standing of the Association both within the Council and the local community and made further work that much more difficult.

In spite of some mishaps along the way, CRREPA is very proud of its achievements during these interesting times.

Eradicating **Juncus acutus* from Garden Island

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HISTORY OF INFESTATION

Sharp Rush, **Juncus acutus,* was first identified on Garden Island in January 1996, infesting a water compensation basin adjacent to the AFL Oval. This area previously had a drain associated with a World War II artesian bore and it is likely that the rush has been present for many years. The basin covers approximately 1.25 ha. The sharp clumps of rush are also found in the playing fields, presenting an occupational health and safety hazard to athletes. The gardeners have tried to kill these clumps by mowing and spraying with Roundup® with gradual success. Scattered clumps have established around the perimeter of the sporting ovals.

1996 TRIALS

In 1996 John Peirce of the Department of Agriculture, WA, offered assistance for a spray trial on Garden Island where the drainage basin is isolated from other vegetation and readily dividable into plots for experimental treatments.

In February 1996 (when the rush was still green), five chemicals (see Table 1.1) were trialed in seven treatments (see Table 1.2). Chemicals were applied by spraying on to the foliage of rush clumps. The spraying was followed by an autumn burn, aimed at killing adult plants, destroying the heavy seed crop held on rushes, and destroying seed held in the ground. Treatments were assessed in January 1997.

KEY RESULTS

For unburnt treatments, a single treatment of imazapyr had the best control (93 per cent). The addition of 2,4-D Amine to hexazinone and sulfometuron improved the control, as did the use of glyphosate with sulfometuron. Where burning had taken place, most of the treatments had given 100 per cent control, the exception being sulfometuron.

It was noted by Parsons and Cuthbertson (1992) that burning is only successful long-term if the roots are then removed or severed to prevent the crown from recovering. Peirce also noted the importance of treating new seedling infestations before extensive root systems are developed. In addition, where the rush occurs under or among native species, the potential impacts on those native species from different herbicides should also be taken into account.

FOLLOW-UP WORK

Follow-up treatments have not been as regular as they should be and, as a result, clumps of Sharp Rush still exist in the compensation basin. Sharp Rush has occasionally been treated opportunistically over subsequent years, primarily with glyphosate (e.g. 1.5 per cent glyphosate, 1 g/L glean, 35 ml/10 L agral). However, follow-up inspections have shown that although the plants initially appear to die back, many eventually resprout from the crown.

OTHER SHARP RUSH INFESTATIONS

Besides the compensation basin, Sharp Rush has been found in other areas on Garden Island, including areas surrounding the sporting ovals and Colpoys Point, but is yet to be found amongst the undisturbed bushland of Garden Island. Biennial weed grid surveys are conducted on Garden Island, assessing 280 evenly distributed grid points throughout the entire island. Sharp Rush has only ever been found in one of these grid points, and has not been documented since the initial survey in 2001. However, it should be noted that the areas in which Sharp Rush occur tend to be associated with the developed grounds of HMAS Stirling, which are excluded from the grid survey. The next survey is scheduled for spring 2006.

FUTURE PLANNED TREATMENTS

Areas of known Sharp Rush infestations were treated with glyphosate in October 2005 and again in May 2006. However, it is evident that the larger clumps are still able to resprout, and therefore the Department of Defence is considering burning the areas this winter/spring. In areas where burning is not practical or safe, clumps will be slashed and subsequent regrowth will be sprayed.

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TABLES

Table 1. Chemicals used in trial.

BRAND	CHEMICAL
Velpar®	Hexazinone
Arsenal®	Imazapyr
Oust®	Sulfometuron methyl
Amine 500®	2,4-D Amine
Roundup CT®	Glyphosate 450

Table 2. Treatments and percentage kill rates as assessed in January 1997.

	HERBICIDE	RATE/10 L WATER	KILL RATE % (NOT BURNT)	BURNT KILL RATE % (BURNT MAY 1996)
1	Hexazinone	54 ml	85	100
2	Imazapyr	60 ml	93	100
3	Sulfometuron methyl	8 g	58	78
4	Hexazinone + 2,4-D Amine	50 + 50 ml	93	100
5	Imazapyr + 2,4-D Amine	50 + 50 ml	93	100
6	Sulfometuron methyl + 2,4-D Amine	8 g + 50 ml	73	100
7	Sulfometuron methyl + Glyphosate	8 g + 30 ml	91	100

Launch of new brochure: "Managing Weeds in Bushland: Sharp Rush, **Juncus acutus*"

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The "Managing Weeds in Bushland: Sharp Rush, **Juncus acutus*" brochure was launched at the workshop. A copy follows on the next two pages. More copies are available by contacting Urban Nature (see the address above).

*Juncus acutus masquerading as *J. pallidus*: the Gosnells experience

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Sub-divisional development processes are often implemented such that essential drainage elements are incorporated into Public Open Space. This has seen many estates being built where a 'constructed wetland' is a necessary function for dealing with surface water and runoff.

The City of Gosnells' procedure is for the Developer to be responsible for maintenance for a period of 2 years; hence Environmental Operations staff does not become familiar with these sites until they are well developed.

Through this mechanism, two sites have come to light where **Juncus acutus* has been provided to a landscape contractor responsible for the implementation of landscape elements. It is now evident that **J. acutus* has been provided as *J. pallidus,* as the stands of Sharp Rush are growing as a very distinct block of specimens amongst an otherwise pure planting of *J. pallidus*. At one estate location, the City has now up to 1000 mature specimens. Fortunately these are in a location of easy access, and plans were underway for the physical removal of these by machine. (Given the success of herbicide control discussed in the workshop it would be prudent for this method to be used.) The City has determined the source of these specimens and has advised the supplier in order that a repeat occurrence may be avoided.

City Officers acknowledge that this situation has occurred through the lack of due diligence and a more rigorous inspection regime has been implemented during the development stages of subdivisional areas.

There is clear evidence that plant suppliers of sedge material have been unwittingly involved in the supply of **J. acutus*. It can be suggested that wider knowledge of the species will assist in the early recognition and control.

Discussion

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GENERAL COMMENTS / DISCUSSION

The following general comments were raised by workshop participants during the discussion session.

1. Workshop participants were requested to record any further Sharp Rush infestations on a list at the workshop (first five records below) or to email new records or localities to the facilitator for inclusion at a later date (records f-i).

	NAME	LOCATION OF NEW RECORDS
a	Elaine Sherry	Warrening Brook, Quindanning, running into Williams River. Very dense.
b	Jill Cowcher	Tributaries of Williams River.
c	Mike Johnson	Hutt River, Port Gregory Road, Jurien Bay area, Lancelin.
d	Kate Brown	Lake Kookalup, Beeliar.
e	Greg Bremner	Rural properties, Victoria/Boundary Road, in the vicinity of Botany Research area.
f	Vicky Hartill	Please note that **J. acutus* has been sighted along the eastern side of Lake Joondalup, Yellagonga Regional Park adjacent to Ariti Avenue. I am in the process of creating a map with photographs of any recorded sightings so when this is more updated I will forward it on to you. The extent of its distribution around the lake is unknown at present, however I feel (just from initial quick ground truthing!!) this is an isolated population and hopefully this is the case.
g	Thelma Crook	We have had a report that **J. acutus* has been planted at Quandong Park development at Seascapes in Mandurah. The person who reported it has rung Mirvac Fini (the developer) to let them know that it is an introduced weed and should be removed. The person reporting it said that she took the seed heads off the plants the first year but hasn't done that again. She also said that it is growing up through the limestone path there.
h	Bethan Lloyd	While I was in Pemberton for a week recently, I noticed small pockets of Sharp Rush around Pemberton. I am worried because after the workshop I realised that since Pemberton is a tourist centre for great attractions along the Donnelly and Warren Rivers, Sharp Rush can easily be spread by visitors moving out from Pemberton to these pristine areas.
i	Richard Clarke (2007)	Population at Dunsborough.

	NAME	LOCATION OF NEW RECORDS
j	Michael Lyons	In 2006, a population of **Juncus acutus* was sighted by DEC on the western bank of the Dalyup River West, on the south side of the bridge on South Coast Highway, about 20km west of Esperance. In April 2007, subsequent survey by the South Coast Regional Initiative Planning Team and the Department of Water mapped the weed's occurrence along the Dalyup River West, from about 60m north of the bridge to about 1.7km downstream (Figure 1). It was also found to be growing west from the bridge along South Coast Highway for about 500m, and around the edges of a wetland on the north side of South Coast Highway, about 1.5km east of the Dalyup River West bridge crossing. It is recommended that these populations be eradicated as soon as possible. It is noted that in the Western Australian Herbarium there is a 1971 collection of **J. acutus* by Arthur McComb from 17 miles west of Esperance (probably near the highway). This population has not yet been relocated.

2. The need for one common name for *Juncus acutus*.
   The name Sharp Rush was decided upon.

3. There is a need to understand that Sharp Rush is a major amenity threat for ovals. The Garden Island experience suggests it is. What is the ecological amplitude of this species in dryland areas; could it invade like Arum Lily? What variety of soils does it grow on?

4. Are compensation basins a source of spread?

5. Restoration/revegetation of areas affected. Some areas are naturally bare; will they recover unaided or do they need artificial cover to stop re-invasion?

6. How does the nutrient status of wetlands affect invasion?

7. Is **Juncus acutus* habitat always bad for fauna or is some good?

8. Problems of control in and impacts on linear reserves (creeks/rivers).

9. The large number of occurrences makes control difficult to prioritise.

10. The problem on farmlands of spread of **J. acutus* from degraded wetlands into productive lands.

11. There is a need to raise local shires' awareness of this weed, because the Wheatbelt/Agricultural Zone is the source of the rest of infestations.

12. There is a need to raise awareness in nurseries (to prevent inadvertent sale of **J. acutus*), and the revegetation industry (eliminating confusion between native and weed species). Educate local governments to clean machines and to prevent spread of contaminated mulch.

13. Investigate funding to manage spread by eradicating outliers.

14. Map distribution with a focus on outliers.

15. Economic effects of Sharp Rush on recreation and agriculture (marginal lands competing with pastures).

16. List **J. acutus* as a declared species.

17. Investigate listing as a weed of national significance.

There is a need for further research to investigate the following:

- Time to flowering
- Seed longevity
- Size/longevity of individuals
- Response of seed to herbicides
- Germination response following fire (both heads and seed bank)
- Length of control program required
- Inundation period response
- Techniques to inhibit germination (seed requires light to germinate)
- Methods of spread (locally and regional)
- Seed predation (by native insects)
- Recovery of native communities post-control, across different habitats
- Native replacements for this weed (restoration techniques)
- Hybridisation occurrence and effects
- Does composting or mulching work (especially in broad acre sites)?

REFERENCES

Clarke R (2007) *Juncus acutus* in Dunsborough. *The Flora Scene* (Newsletter of the Bunbury Regional Herbarium, Department of Environment and Conservation) Department of Environment and Conservation, **2**(1), 4.

FIGURES

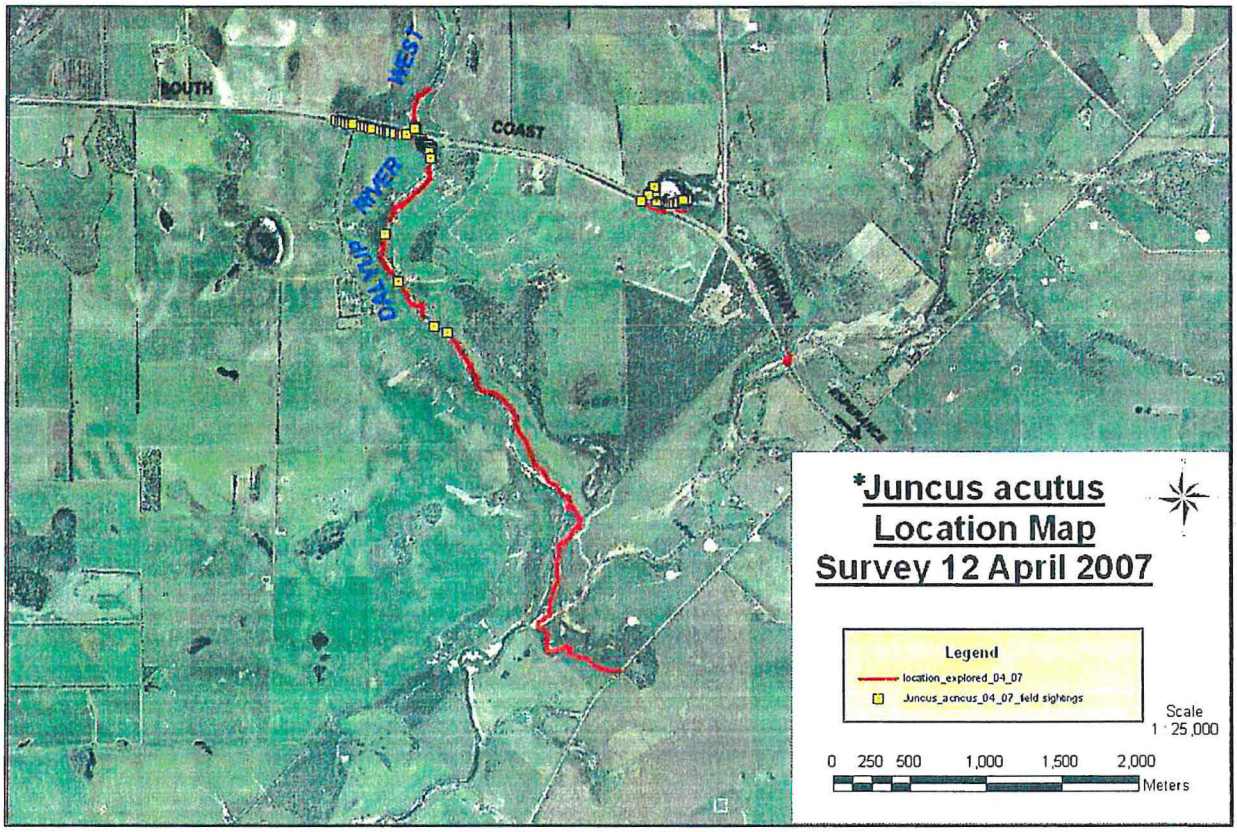

Figure 1. *_Juncus acutus_ populations in the vicinity of the Dalyup River West, approximately 20km west of Esperance. Mapping was initiated by DEC, and subsequent survey in April 2007 was conducted by the South Coast Regional Initiative Planning Team and Department of Water.