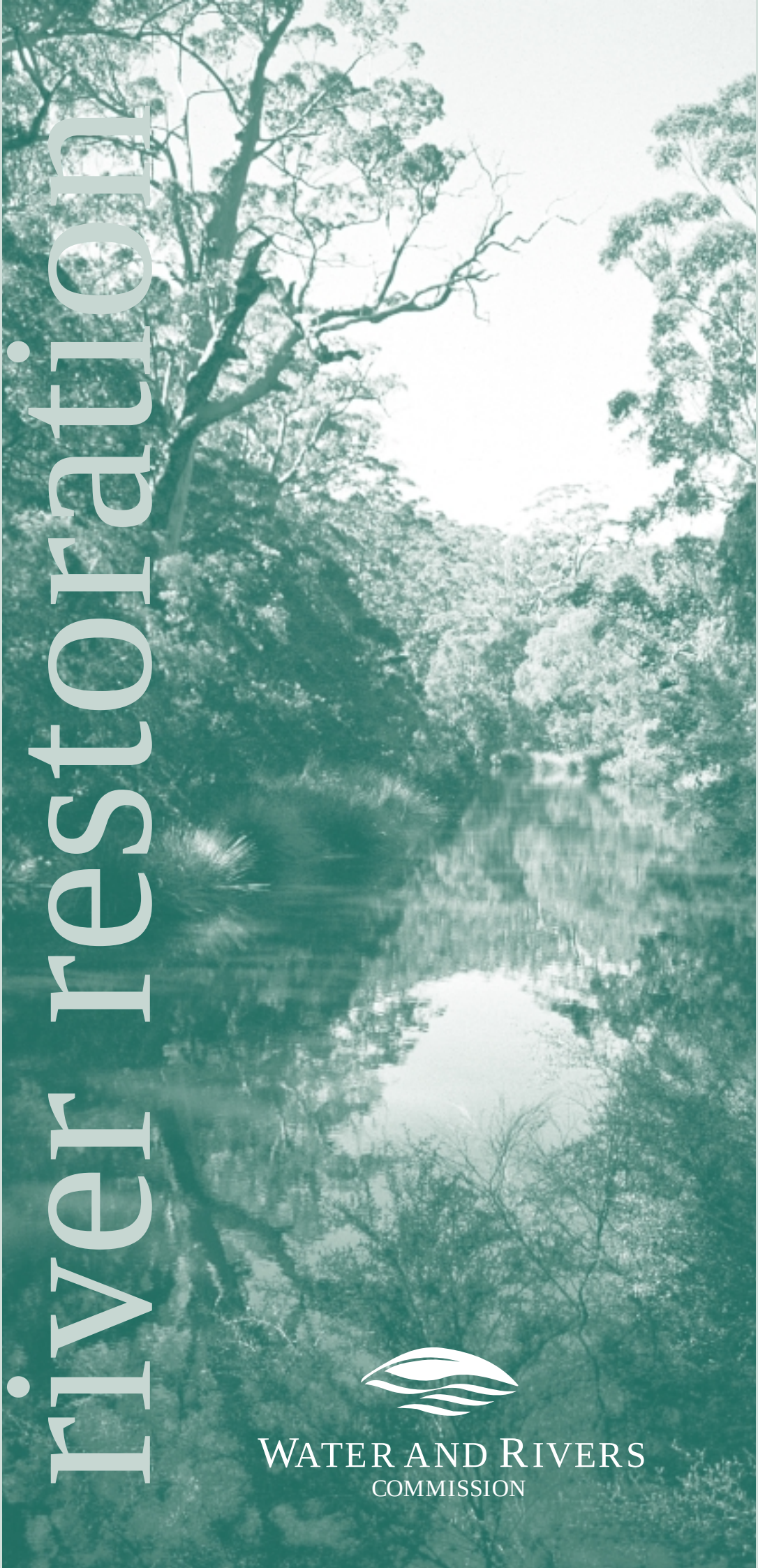
river restoration



Using rushes and sedges in revegetation of wetland areas in the south west of WA

WATER AND RIVERS COMMISSION

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Report No. RR 8

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USING RUSHES AND SEDGES IN REVEGETATION OF WETLAND AREAS IN THE SOUTH WEST OF WA

Prepared by
Linda Taman

Jointly funded by

Natural Heritage Trust

WATER AND RIVERS COMMISSION

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Foreword

Many Western Australian rivers are becoming degraded as a result of human activity within and along waterways and through the off-site effects of catchment land uses. The erosion of foreshores and invasion of weeds and feral animals are some of the more pressing problems. Water quality in our rivers is declining with many carrying excessive loads of nutrients and sediment and in some cases contaminated with synthetic chemicals and other pollutants. Many rivers in the south-west region are also becoming increasingly saline.

The Water and Rivers Commission is responsible for coordinating the management of the State's waterways. Given that Western Australia has some 208 major rivers with a combined length of over 25 000 km, management can only be achieved through the development of partnerships between business, landowners, community groups, local governments and the Western Australian and Commonwealth Governments.

The Water and Rivers Commission is the lead agency for the Waterways WA Program, which is aimed at the protection and enhancement of Western Australia's waterways through support for on-ground action. One of these support functions is the development of river restoration literature that will assist Local Government, community groups and landholders to restore, protect and manage waterways.

This document is part of an ongoing series of river restoration literature aimed at providing a guide to the nature, rehabilitation and long-term management of waterways in Western Australia. It is intended that the series will undergo continuous development and review. As part of this process any feedback on the series is welcomed and may be directed to the Catchment and Waterways Management Branch of the Water and Rivers Commission.

Using rushes and sedges in revegetation of wetland areas of the south west of WA

Introducing rushes and sedges

While many people are familiar with the trees, shrubs and herbaceous plants of their area, few are familiar with the rushes and sedges. Many of the species look similar to the untrained eye, and are easily confused with weed species.

Rushes and sedges form an extremely important component of wetlands, rivers and estuaries of the coastal areas of the south west. They provide food and habitat for a wide range of aquatic species, assist with aeration of the sediments and filter and bind pollutants, particularly nutrients, that enter the ecosystem. In addition they are often found at the land-water interface, and play an important role in stabilizing the banks. The root mass binds the soil, while the many stems reduce the impact of wave action or fast-flows at the water's edge.

Rushes and sedges reproduce by seed, but many species set little viable seed and extend their range by forming large clonal colonies through underground spread of rhizomes. Some species produce a high percentage of viable seed, but the seed has a complicated dormancy pattern which may require many years of weathering to break. Fortunately many of the species which are difficult to grow from seed are readily propagated from tissue culture or division of rhizomes. Tissue culture involves the extraction of embryos from viable seed and the production of seedlings grown in sterile media within the laboratory.

Many of the rushes and sedges spend much of their life with their roots submerged, and in order to survive, have developed air-filled cells within their root systems, called aerenchyma. This allows the plants to draw oxygen down into their rhizomes, from where it may diffuse into the sediments. Many microbial organisms which break down organic matter depend on well oxygenated sediments to survive. Thus many rushes and sedges promote removal of nutrients from waterbodies through the creation of habitat for suitable bacteria and fungi, as well as by the nutrients they take up in order to grow.

Botanically, rushes are members of the Juncaceae family, while sedges are members of the Cyperaceae family. Unfortunately the common names are very confusing, with many members of the Cyperaceae commonly called rushes. The Typhaceae family is a small family but extremely common, and these plants are often called Bulrushes. This manual section will deal with the common rushes, sedges and bulrushes of the south west of Western Australia, and their use in wetland, river and estuary restoration. There are few reference books available to assist with identification of these species. However there are two publications by the Water and Rivers Commission and Department of Conservation and Land Management in Perth, *Native Vegetation of Freshwater Rivers and Creeks in South Western Australia (1997)*, and *Native Vegetation of Estuaries and Saline Waterways in South Western Australia (1997)*, and a book produced in New South Wales by Geoff Sainty et al (1994) *(Waterplants in Australia: A Field Guide)* which are quite useful.

The other similar family of sedge-like plants is the Restionaceae, or Southern Rushes, many of which are dryland plants. This large and diverse group are not described in this section, but a new publication by Meney and Pate (1999), *Australian Rushes*, will assist in identifying these species.

Wetland zones

Rushes and sedges have specific hydrological requirements. The areas in which they will grow are determined largely by the minimum and maximum water levels. Very few of these plants are adapted to a static water level, as the wetlands, rivers and estuaries of the southwest of Western Australia generally have a large fluctuation in water level from winter to summer. Although stream and river systems vary considerably, the following hydrological zones for rushes, sedges and other aquatic plants can be defined along most watercourses.

- **Submergent zone**

  This zone has surface water for a good proportion of the year. Submergent plants grow beneath the water surface, although their leaves may float on the surface, and the flowering spikes may extend above the water. Many submergent species may live comfortably as terrestrial plants as the water drops, or may become dormant until water levels rise again. There are a range of plant families which live as submergents, but they do not include any of the rushes and sedges. The plants in this zone provide aquatic habitat, stabilise the stream bed, slow water flow, assist in nutrient removal and help to cool the water surface by shading.

- **Emergent zone**

  The emergent zone supports plants which have their roots submerged beneath the water for at least some of the year, but extend their leaves and stems above the water surface. This area can range from 1m deep in winter to damp in the driest part of summer. Many species from the Cyperaceae and Typhaceae families live in this zone, as well as one species from the Juncaeae.

  This zone is extremely important for many fauna species, providing shelter and food along the shallow edges. It is also the most important area for erosion control, as this is the area in which most erosion occurs, and also the most important for nutrient and sediment removal.

- **Damp zone**

  The damp zone, as its name suggests, is permanently damp or damp near the surface for most of the year, without having standing water, except for flood events. Almost all of the rushes and sedges can live happily in this zone. The damp zone often extends for a large distance across the floodplain. It is very important as a filtering zone for surface runoff entering the system, as sediment and debris settle out while water passes through this zone. In flood events the dense vegetation prevents erosion, and provides habitat for a wide range of fauna, particularly birdlife.

- **Ephemeral zone**

  This zone is quite dry for much of the year, and may only become wet in flood events. It is the interface between the bushland and the riparian zone. There are a few hardy species of rush and sedge which will live in this zone, members of the Cyperaceae and Juncaceae families.

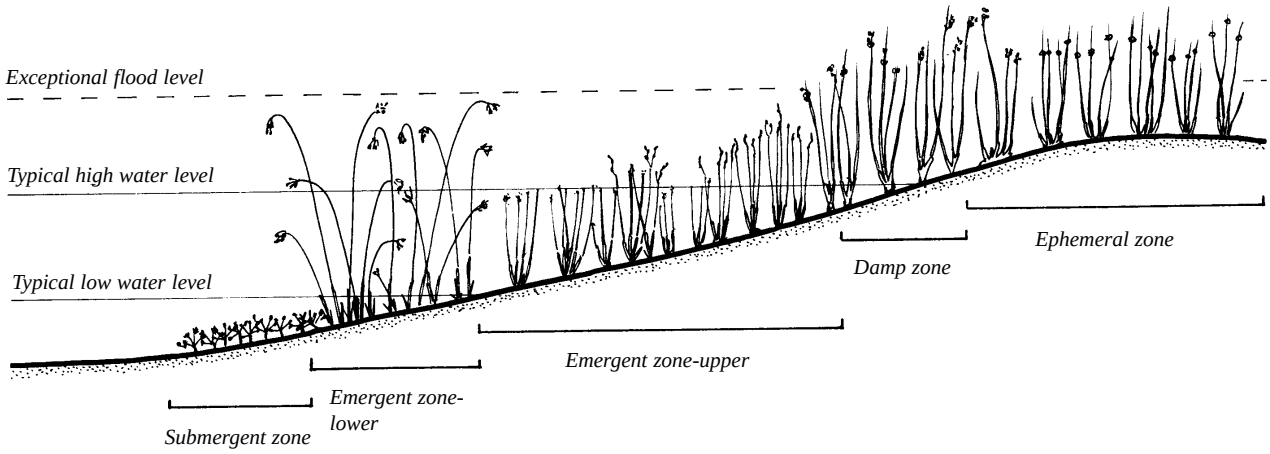


Figure 1: Wetland zones and typical distribution of some sedge and rush species.

A description of the common rushes, sedges, bulrushes and submergents of the south west of WA

The following descriptions include only the most common species, and those available commercially for rehabilitation projects. Common weed species are also included, as it is important not to mistake these for native species.

Family: *Juncaceae*

The species in this family are all tufting, with cylindrical stems. With the exception of the Shore Rush, all species are found in the damp or ephemeral zones. They have seed capsules in clusters near the end of their stems, which have large quantities of microscopic dust-like seed.

Name:	*Juncus kraussii* (Shore Rush)	**Name:**	*Juncus pallidus* (Pale Rush)
Location:	All through the SW	**Location:**	All through the SW
Soil Type:	Sand, occasionally clay	**Soil Type:**	Sand, clay
Water Quality:	Fresh to saline	**Water Quality:**	Fresh
Water Depth:	Damp zone to 30cm into emergent zone	**Water Depth:**	Ephemeral to damp zone
Propagation:	Collect seed Jan-Feb	**Propagation:**	Collect seed in Dec-Jan
Description:	Clumping rush to 1.2m, forms dense colonies along banks. Excellent for habitat and bank stabilisation.	**Description:**	Clumping rush to 1.5m, used to increase biodiversity and stabilise floodplain.
Name:	*Juncus pauciflorus* (Loose Flower Rush)	**Name:**	*Juncus subsecundus* (Finger Rush)
Location:	All through the SW	**Location:**	All through the SW
Soil Type:	Sand, clay	**Soil Type:**	Clay, occasionally sand
Water Quality:	Fresh	**Water Quality:**	Fresh
Water Depth:	Damp zone	**Water Depth:**	Ephemeral to damp zone
Propagation:	Collect seed Jan	**Propagation:**	Collect seed Jan-Feb
Description	Clumping rush to 1.2m, used to increase biodiversity and stabilise banks.	**Description**	Smaller rush to 1m, used to increase biodiversity and stabilise floodplain.
Name:	*Juncus holoschoenus* (Jointleaf Rush)	**Name:**	*Juncus amabilis* (Blue Rush)
Location:	Common south of Perth	**Location:**	Common in the south west corner around Bunbury
Soil Type:	Sand	**Soil Type:**	Sand/clay
Water Quality:	Fresh to brackish	**Water Quality:**	Fresh
Water Depth:	Damp zone	**Water Depth:**	Damp zone
Propagation:	Collect seed Jan	**Propagation:**	Collect seed Jan
Description	Small rush to 0.8m, used for biodiversity and bank stabilisation. Easily confused with the weedy species *J. articulatus* and *J. microcephalus.*	**Description**	Clumping rush to 1.5m, used for for biodiversity and bank stabilisation.

Some species of rush are weeds, and they can be a major problem in rehabilitation due to the large viable seed store they produce in the soil. There are three main weedy species of Juncaceae, and these are described below:

Juncus articulatus: This species is quite soft and low growing, with hollow articulated branching stems. It is found in the damp zone.

Juncus acutus: Spiny Rush is a tall rush to 1.5m, with stiff leaves having a very sharp tip, which gives it the appearance of a sea urchin. The seedheads have large red/brown capsules, and the species will grow in either brackish of fresh conditions. It is highly prevalent in the rural areas surrounding Perth.

Juncus microcephalus: Growing to 1m tall, this rush has large articulated stems, which are easy to 'pop' with the fingers. A large loose seedhead contains many viable seeds.

Family: *Cyperaceae*

This is a large and diverse family, and includes many of the most common wetland plants. Common groupings within the family include the *Carex* species, Twig Rushes, Club Rushes, Sword Sedges, Saw Sedges and Spike Rushes.

Carex species

These species are all grassy in appearance, with the majority tufting rather than rhizome spreading.

There is one weed species in the *Carex* family:

Carex divisa is common on the Swan Coastal Plain down to Bunbury, and looks very similar to *Carex inversa*. It is a rapid rhizome spreading species which can be difficult to control.

Recently planted Carex fascicularis *(Tassel Sedge) stabilising the banks of Bennett Brook.*

Name:	*Carex appressa* (Tall Sedge)	**Name:**	*Carex fascicularis* (Tassel Sedge)
Location:	All areas of the SW	**Location:**	All areas of the SW
Soil Type:	Sand/clayey loam	**Soil Type:**	Sand, occasionally clay
Water Quality:	Fresh to brackish	**Water Quality:**	Fresh
Water Depth	Damp zone to 10cm into the submergent zone	**Water Depth:**	Damp zone to 20cm into the emergent zone
Propagation:	Collect seed in Dec-Jan	**Propagation:**	Collect seed in Feb/Mar
Description:	Tall tufted sedge to 1.5m, grassy, sharp edged rough leaves similar to Pampas grass. Tall flowering spike on triangular stem. Useful for habitat, bank stabilisation, weed control.	**Description:**	Tufted sedge to 1m with grassy leaves. Seedheads form brown drooping tassels on a triangular stem. Useful for bank stabilisation aquatic habitat, weed control. Fast growing.

Name:	*Carex inversa* (Knob Sedge)	**Name:**	*Carex tereticaulis* (Tube Sedge)
Location:	All through the SW	**Location:**	All through the SW, but rare. Currently P1 classification.
Soil Type:	Sand	**Soil Type:**	Sand/clay
Water Quality:	Fresh to saline	**Water Quality:**	Fresh
Water Depth:	Damp Zone	**Water Depth:**	Ephemeral to damp zone
Propagation:	Collect seed Dec-Jan	**Propagation:**	Collect seed Dec-Jan
Description:	Rhizome spreading sedge to 0.5m, excellent for weed control, fire resistant and good for bank stabilisation. Fast growing. Easily confused with the weed species *Carex divisa*.	**Description:**	Tufted, grassy sedge to 1m. Useful for stabilising drier banks, biodiversity.

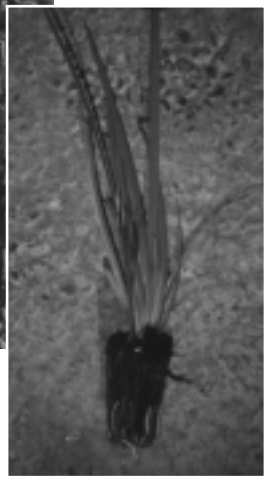
Twig rushes

A diverse group, which all look different from each other. Most are rhizome spreaders, with some spreading faster and further than others. Seeds are large nuts held in numerous spikelets, up to 2mm long.

A thick stand of Baumea articulata *(Jointed Twig Rush) on the edge of Bennett Brook.*

Name:	*Baumea arthrophylla* (Sparse Twig Rush)	**Name:**	*Baumea articulata* (Jointed Twig Rush)
Location:	All through the SW	**Location:**	All through the SW
Soil Type:	Sand/clay	**Soil Type:**	Sand/clay
Water Quality:	Fresh/brackish	**Water Quality:**	Fresh
Water Depth:	Damp zone to 1m into emergent zone	**Water Depth:**	Damp zone to 1m into emergent zone (This species can tolerate water levels dropping 1m below the surface in summer)
Propagation:	Difficult, transplant only	**Propagation:**	Tissue culture or transplant
Description:	Drooping, narrow stemmed, rhizome spreading species which is useful for aeration of the sediments, aquatic habitat and bank stabilisation	**Description:**	Tall sedge to 2m with firm, articulated stems, rhizome spreader useful for aeration of sediments, aquatic habitat and bank stabilisation.

Name:	*Baumea juncea* (Bare Twig Rush)	**Name:**	*Baumea preissii* (Broad twig Rush)
Location:	All through the SW	**Location:**	All through wetter areas of the SW
Soil Type:	Sand/clay	**Soil Type:**	Sand, occasionally clay
Water Quality:	Fresh/brackish	**Water Quality**	Fresh
Water Depth:	Ephemeral zone to 30cm into emergent zone	**Water Depth:**	Damp zone to 30cm into emergent zone
Propagation:	Tissue culture or transplant	**Propagation:**	Tissue culture or transplant
Description:	Rhizome spreading sedge with thin blue stems to 1m which forms dense meadows. Excellent for bank stabilisation of dry banks and weed control.	**Description:**	Slow rhizome spreading sedge to 1m with flat stems and leaves up to 3cm wide, and pendulous seedheads. Useful for aquatic habitat, weed control and bank stabilisation.
Name:	*Baumea rubiginosa* (River Twig Rush)	**Name:**	*Baumea vaginalis* (Sheath Twig Rush)
Location:	All through SW	**Location:**	All through SW
Soil Type:	Sand/clay	**Soil Type:**	Sand/clay
Water Quality:	Fresh	**Water Quality:**	Fresh
Water Depth:	Damp zone to 20cm into emergent zone	**Water Depth:**	Damp zone to 40cm into emergent zone
Propagation:	Tissue culture or transplant	**Propagation:**	Tissue culture or division
Description:	Looks similar to *B preissii*, but leaves are narrower, seedhead is erect and seeds are yellow. Useful in clay soils along banks for stabilisation, and for weed control.	**Description:**	Clumping sedge to 1.8m with blue blue stems and sparse seedheads. Useful for aeration of sediments, aquatic habitat and bank stabilisation.



Baumea preissii *growing in a field of* Centella asiatica *on the edge of Bennett Brook.*

A cell of Baumea preissii

Club rushes

This group consist of three sub-groups, *Schoenoplectus*, *Isolepis* and *Bolboschoenus*. All are totally different from each other, but all carry nuts in groups of spikelets on the stems.

Schoenoplectus validus *(Lake Club Rush) being grown in strips ready for planting.*

Name:	*Schoenoplectus validus* (Lake Club Rush)	**Name:**	*Schoenoplectus pungens* (Sharpleaf Club Rush)
Location:	Swan Coastal Plain down to Leeuwin Leeuwin and some inland areas	**Location:**	Bunbury and surrounding districts
Soil Type:	Sand	**Soil Type:**	Sand/peat
Water Quality:	Fresh to semi-saline	**Water Quality:**	Fresh
Water Depth:	Permanently damp zone to 1m into emergent zone	**Water Depth:**	Damp zone to 40cm into emergent zone
Propagation:	Collect seed Feb or transplant. Seed requires warm weather to germinate.	**Propagation:**	Collect seed in Feb, or transplant
Description:	Extremely rapid grower in hot weather, this 2.5m sedge is recommended nutrient stripping, aquatic habitat, bank stabilisation and weed control. May spread and block narrow channels.	**Description:**	Rapid rhizome spreader with triangular stems to 1m. Good for nutrient stripping, weed control and bank stabilisation
Name:	*Isolepis nodosa* (Knotted Club Rush)	**Name:**	*Bolboschoenus caldwellii* (Marsh Club Rush)
Location:	Coastal areas of the SW	**Location:**	All through the SW
Soil Type:	Sand	**Soil Type:**	Sand/clay
Water Quality:	Fresh to saline	**Water Quality:**	Fresh to brackish
Water Depth:	Ephemeral to damp zone	**Water Quality:**	Damp zone to 20cm into the emergent zone
Propagation:	Collect seed Jan-Feb	**Propagation:**	Collect seed in Jan/Feb
Description:	Clumping plant to 1m, often found on coastal dunes. Excellent stabiliser of loose sands, very hardy and salt tolerant.	**Description:**	Rapid spreading rhizomatous grassy sedge to 0.8m with triangular stems. Dies back in winter, but roots help to stabilise banks. Good aquatic habitat.

There is one *Isolepis* species which is a common weed species:

Isolepis prolifera reproduces vegetatively by sprouting at the end of its stems, which bend till they reach the ground and take root. This species grows in the emergent zone and is difficult to eradicate.

Sword sedges

The *Lepidosperma* family is quite large, and many of the species are bushland plants. All species have nuts which are held in bunches of spikelets on the stem, and most have wide flat leaves and stems of varying widths. Most species are clumping, with one which spreads rapidly from rhizomes. Most of the species produce little viable seed.

Lepidosperma tetraquetrum - *4-angled sedge.*

Name:	*Lepidosperma effusum* (Spreading Sword Sedge)	**Name:**	*Lepidosperma gladiatum* (Coast sword Sedge)
Location:	Common south of Perth	**Location:**	Coastal areas of the SW
Soil Type:	Sand/clay	**Soil Type:**	Sand
Water Quality:	Fresh	**Water Quality:**	Fresh to brackish
Water Depth:	Damp zone	**Water Depth:**	Ephemeral to damp zone
Propagation:	Tissue culture, seed or transplant	**Propagation:**	Tissue culture, seed or transplant
Description:	A large clumping 2m sedge which is good for bank stabilisation.	**Description:**	A clumping sedge to 1.2m which is often found on coastal dunes. Excellent stabiliser of loose sands.
Name:	*Lepidosperma longitudinale* (Pithy Sword Sedge)	**Name:**	*Lepidosperma tetraquetrum* (Angle Sword Sedge)
Location:	All through the SW	**Location:**	All through the SW
Soil Type:	Sand/clay	**Soil Type:**	Sand/clay
Water Quality:	Fresh	**Water Quality:**	Fresh
Water Depth:	Ephemeral to 20cm into emergent zone	**Water Depth:**	Damp zone
Propagation:	Transplant	**Propagation:**	Tissue culture, seed or transplant
Description:	Rapid spreading sedge to 1m which forms dense meadows on the floodplain. Excellent for stabilisation of banks and floodplain, and for weed control, but difficult to establish.	**Description:**	Clumping plant with slow rhizome spread to 2m, with rectangular stems. Excellent bank stabiliser and weed control in ephemeral streams in clay soils.

Saw sedges

There are many dryland species of Saw Sedge, and a few which are associated with wetter areas. All species are grassy and tufted, with erect seedheads containing spikelets with nuts.

Name:	*Gahnia decomposita* (Weeping Saw Sedge)	**Name:**	*Gahnia trifida* (Coast Saw Sedge)
Location:	All through the SW	**Location:**	All through the SW
Soil Type:	Sand/clay	**Soil Type:**	Sand
Water Quality:	Fresh	**Water Quality:**	Fresh to saline
Water Depth:	Damp zone	**Water Depth:**	Damp zone
Propagation:	Transplant, seed	**Propagation:**	Transplant, seed
Description:	Large grassy tussock to 2.5m resembling Pampas Grass with pendulous seedheads. Good bank stabiliser and habitat plant in clay lined streams.	**Description:**	Large grassy tussock to 1.5m which is very useful in habitat creation and weed control in saline areas.

Spike rushes

There are only two Spike Rushes in the SW, and both have a single spike on the tip of the stem which contains many nuts.

Name:	*Eleocharis acuta* (Spike Rush)	**Name:**	*Eleocharis sphacelatus* (Tall Spike Rush)
Location:	All through the SW	**Location:**	Northern wetlands around Perth
Soil Type:	Sand/clay	**Soil Type:**	Sand/clay
Water Quality:	Fresh	**Water Quality:**	Fresh
Water Depth:	Damp zone to 30cm into emergent zone	**Water Depth:**	Damp zone to 1m into emergent zone
Propagation:	Tissue culture or transplant	**Propagation:**	Tissue culture or division
Description:	Rapid rhizome spreading plant to 0.6m which can tolerate quite dry conditions in summer. Very useful for aquatic habitat and bank stabilisation in clay areas.	**Description:**	Tall rush to 2m which can tolerate deep water. Useful for habitat, bank stabilisation and nutrient stripping.

Cyperus species

Most of these species are weeds, but there is a native Cyperus which is found to the north and east of Perth. It has 3-6 bracts at the tip of the cylindrical stems, which contain a cluster of spikelets containing nuts. The nuts germinate on the parent plant and take root when their weight causes the stem to droop to touch the ground.

There are a large number of weed species in this family.

Cyperus gymnocaulis *showing new olantlets sprouting from the seedheads.*

Name:	*Cyperus gymnocaulis* (Spiny Flat Sedge)
Location:	Perth, eastern wheatbelt, north of Perth to Kalbarri
Soil Type:	Sand/clay
Water Quality:	Fresh to saline
Water Depth:	Damp zone to ephemeral zone
Propagation:	Seed, or plantlets growing on seedhead
Description:	Tufted plant to 1m which can tolerate quite dry conditions in and is quite saline tolerant. Very useful for bank stabilisation in saline areas.

Bulrush species

There is an introduced and a native species of Bulrush in the south west. The introduced species is taller and more aggressive, with wider leaves and infloresence.

Typha orientalis is the introduced species of Bulrush, and it is an aggressive weed of wetland systems which rapidly forms monocultures.

Name:	*Typha domingensis* (Native Bulrush)
Location:	All through the south west
Soil Type:	Sand or clay
Water Quality:	Fresh or saline
Water Depth:	Damp zone to inundation of 1m
Propagation:	Seed
Description:	Grassy looking plant with rapid rhizome spread.

Aims of revegetation

Although there are often a number of aims within a stream restoration program, there are usually one or two which will take priority. The main aims need to be defined at the beginning of the project, as aspects such as species selection, site selection and timing of the project can be varied to achieve specific aims.

The most common objectives in a restoration project include the following:

- **Erosion control**

  The erosion of stream banks causes loss of fringing vegetation as well as changing the channel shape and depositing sediment downstream. Erosion can be caused by increased volume and speed of flow through the channel bed, by loss of native fringing vegetation, or more commonly by a combination of the two. Increased flow is quite difficult to manage, and it is usually much easier to restore the original fringing vegetation.

  Annual weeds and grasses, which often replace the original vegetation, have shallow root systems, which cannot prevent soil erosion. The local native species which grow naturally along streams include rushes, sedges, trees and shrubs. The tangled root mass which results is excellent for bank stabilisation.

  For many stream and river systems, the vegetation at the land/water interface consists of rushes and sedges. These often grow in dense bands which can extend metres out into the water as well as up the banks into the ephemeral zone. The flexible stems of these emergent species reduce the energy of the water flow along the banks, and reduce the impact of wave wash.

- **Creation of fauna habitat**

  The prime objective of a restoration project may be to recreate fauna habitat, perhaps in the form of a wildlife corridor along a stream course. The fauna may include mammals, birds, reptiles, amphibians or aquatic fauna. It is important to know the specific habitat requirements of the fauna before planning the project. Fauna present at the site may also influence timing of weed control. For example, a project to enhance Quenda[1] habitat would need to concentrate on planting dense shrubby understorey layers. Weed assemblages at the site may be providing shelter for Quendas currently residing in the area, and it would be important to leave sufficient cover for the animals until the native understorey is re-established.

  Dense rush and sedge beds (particularly the taller species) provide excellent nesting habitat for a number of water birds, and also provide a sheltered environment for aquatic invertebrates and native fish.

- **Increase in biodiversity of flora**

  If the aim of the project is to increase the diversity of flora and fauna, it is important to investigate the species and structure of the original vegetation. If there is an area of intact vegetation nearby, this can be used as a template. If this is not available, historical records may give information on the natural vegetation. Failing this, an estimate of plant species composition can be made from similar sites and herbarium records. It should be noted that riparian zone vegetation can be low in diversity in its pristine state.

  Where possible it is best to use local provenance stock, which is stock produced from seed or division from plants growing within the local area. Local provenance stock can be requested from nurseries when placing orders. This helps to preserve genetic differences between species growing in different regions. To obtain a wide variety of species, several restoration techniques may be necessary at the same site; for example direct seeding of suitable species, planting of seedlings of species available from nurseries, and transplanting of those which are not available in any other form.

- **Restoration of saline environments**

  Many of our rivers have become increasingly saline and waterlogged, and the original riparian vegetation is no longer able to survive in the changed environment. Where environments are drastically altered, it may be necessary to select species for restoration that were not originally found at the site, but are able to cope with the new conditions. Several of the rushes and sedges are extremely salt tolerant, and can be used to stabilise banks and create habitat on saline watercourses.

[1] Quenda is small marsupial, otherwise known as the Southern Brown Bandicoot.

- **Nutrient stripping**

  Eutrophication is a problem in many river systems of the south west. Rushes and sedges can be used both to prevent additional nutrients from entering stream systems, and to aid in removing them from a system. Dense plantings of rushes and sedges in the riparian zone will slow surface runoff into the wetland system. As the water slows, sediment and debris will settle out into the rush beds before reaching the waterbody. Sediment, especially clay, often contains attached nutrients. Debris is usually composed of organic matter, including animal excrement. Removing both of these elements from surface runoff reduces the nutrient loading of the river or creek.

  The plants themselves are also rapid growers, and use nutrients to grow, as well as storing some in their rhizomes. The best species for nutrient removal are those which are able to grow in permanent water, have large rhizomatous root systems and are rapid growers. *Schoenoplectus validus*, *Eleocharis sphacelatus* and *Baumea articulata* fall into this category.

- **Community awareness**

  A valid reason for commencing a river restoration project is to raise the awareness of the local community on the issues surrounding river degradation. If this is to be the main aim of the project it is important to choose a site which will be highly visible, or to advertise the project well. In addition, the site should be fairly easy to restore, so that a sense of achievement can be felt by the participating community. The site should be accessible and the weeds controllable!

Collecting site information

Once the main aim of the project has been decided, data about the proposed restoration site should be collected. The following information is important to the success of the project:

- **Hydrology**

  It is extremely important to know the hydrology of the waterbody you are restoring, in order to plant wetland species in the correct zones. Record the average winter water levels, as well as the period for which water levels are high. Also record where the water levels fall to in mid-summer (usually Feb-Mar). This may require taking core samples to ascertain where the groundwater lies. From this information, define the wetland zones. Also note where there is flowing water during the year, as these sites will be prone to erosion. Tidal influences may also be important.

- **Weeds**

  Record the weeds present at the site, and also weeds present in nearby areas or upstream, and be sure to check weed species at different times of the year. Often there are many annual species which are not obvious until spring. A good reference for weed identification is ‘Western Weeds: A Guide to the weeds of Western Australia, by Hussey et al (1997). Weed mapping of the site may give a clearer picture of the problem. Be aware that as you remove one suite of weeds, another may take its place.

- **Native plant species**

  Identify any indigenous plant species present at the site, and the zone in which they are growing. Record species abundance and distribution (do they tend to grow together in clumps, or are they evenly distributed throughout the zone) to determine a planting plan which will resemble the natural environment. If necessary, investigate historical records and old photos to determine the species list for the area, or do a flora survey of an area of nearby intact vegetation.

- **Soils**

  Identify the soil types at your project site. There may be a mosaic of soil types within a project site, with different combinations of species present as the soil changes.

- **Water quality**

  Determine the basic parameters of water quality for the waterbody. Of most significance are salinity and nutrient levels.

- **Human use**

  It is important to know the human use of the area before beginning a restoration project. It is counter-productive to begin replanting if the seedlings will be trampled by human traffic or destroyed by trail bikes. If these issues are a problem, they need to be dealt with by creating walk trails or fencing before the project begins.

- **Fauna**

  Presence of pest species such as rabbits and grasshoppers can damage rushes and sedges, and if there is a likelihood of these species being a problem, control should be carried out before or after planting. Also note the presence of native fauna, as removal of some weed species may have a detrimental effect on some animals.

Revegetation techniques

There are several methods which can be used to revegetate sites using rushes and sedges:

- **Natural regeneration**

  If there are existing stands of rhizome spreading species at a site, these can be encouraged to regenerate the area by fencing out stock or controlling weed species.

- **Direct seeding**

  Direct seeding can be unpredictable in wet sites for a number of reasons. If the site is subject to surface water flow, the seeds may be washed away, to germinate somewhere far downstream. In addition, the seedlings of species such as Juncus stay small for quite a long time, and are susceptible to competition from weeds. In non-flowing systems, direct seeding may provide a cheap and cost-effective method of revegetation. If direct seeding is to be trialled, it should be carried out in spring, the site should be damp and weed free, and follow-up weed control should be carried out regularly. Seed should be mixed with dry sand or sawdust before spreading.

- **Seedlings**

  It is quite easy to propagate many species in a community nursery or at home. The species which have been identified above as able to be propagated from seed should be germinated as for any other native seed, and prefer warm temperatures and ample light. They are generally not smoke responsive apart from the Saw Sedges. The *Juncus* seed needs to be used very sparingly, as the seed is so small. A tiny pinch of seed is sufficient for a seedtray. These seeds readily germinate, and the masses of tiny seedlings should be regularly fertilised to enable them to grow quickly, as they can be prone to mass deaths.

  If attempting to germinate the more difficult species such as *Baumea*, be prepared to wait 3-4 months for germination, as weathering appears to play an important role in breaking the dormancy of the seeds.

  Many rushes and sedges are available from commercial nurseries. The cheapest option available is cells or small plugs. Many species can also be obtained in 70ml pots, 140ml pots, mats or strips. The choice of size will depend upon many factors such as weed density, depth and velocity of winter water flows, and the prevalence of waterbirds. Larger pot sizes will provide a larger root stock in proportion to leaf stock, which is useful in highly erosive sites. As many waterbirds will pull plants out of the ground, small plants will need to be netted. Strips and mats contain larger plants, and are often used where areas will be inundated relatively soon after planting, or to stabilise banks quickly.

  Planting should be carried out in spring or summer, unless the site is in the ephemeral zone, which should be planted in winter. Most rushes and sedges do their growing over the warmer months. If they are planted in winter, they are relatively dormant and do not establish good root systems quickly, leaving them susceptible to being washed away in winter floods.

- **Transplanting**

  Some species such as *Lepidosperma* are difficult to obtain except through transplanting, and others which are rapid rhizome spreaders are easier to propagate by division than seedlings. Rushes and sedges may be transplanted from areas which are to be cleared for development, or small amounts can be removed from well established beds. Spaces created by transplanting are prone to weed infestation, and it is important to carry out weed control if necessary. The beds should be allowed to fully recover before further transplants are carried out. Care needs to be taken that weeds or soilborne diseases are not also transplanted with the plants!

  It is also feasible to transplant rhizome spreading species into an area which can be used as a permanent source for transplant stock. This may be an existing pond or dam, or may be created in a nursery situation by making beds using pond plastic or coreflute (available from hydroponic suppliers).

Transplants should be carried out during winter or spring. The clumps removed should be as large as possible to minimise root disturbance, and the plant mass should be cut back by a third.

Weed control

There are usually a range of weed species present at a given site, and it is necessary to prioritise species for control. The following checklist can be used to assist prioritisation:

- **Aggressiveness**

  Is the weed actively invading the existing indigenous vegetation, causing an on-going loss?

- **Prevention of natural regeneration**

  A weed species may not be causing loss of existing native vegetation, but it may be preventing regeneration of species by seed or rhizome spread.

- **Fire risk**

  Some weed species (e.g. Bulrush) greatly increase the fire risk in a wetland system, leading to loss of native vegetation such as Paperbarks.

- **Negative aspects of removal**

  Weeds are part of an existing ecosystem, and often removing them will have a detrimental effect. For example, removing Watsonia from a riverbank may cause massive erosion, or loss of habitat for Bandicoots.

- **'Maintainability'**

  What resources do you have to carry out the follow-up which will be necessary to maintain your site. In higher rainfall areas, the amount of time and effort needed for follow-up weed control can be ten times more than that required for the initial project. If you don't have resources for adequate weed control over the longer term, reduce the amount of weed control that you attempt.

Weed control methods

There are many methods and combinations of methods that can be used to achieve effective weed control. Methods chosen will depend on resources available, the species to be controlled and the characteristics of the site. Correct timing and follow-up are crucial to the success of weed control, and a good reference is 'Managing Perth's Bushland' by Scheltema and Harris (1997).

- **Hand removal**

  Suitable for removal of annual weeds, and where there is a large supply of labour, or a small amount of weed infestation.

- **Drowning**

  In wetland situations, rising water levels can be used to drown weed species such as the introduced Bulrush and Kikuyu. Bulrush needs to be cut beneath the water level and grassy weeds can be cut and covered with weighted black plastic as water levels are rising at the start of winter.

- **Removal of seedheads**

  Where the resources of the group are insufficient to eradicate a weed species, removal of the seedheads of species such as the introduced Bulrush will help to prevent new seedlings from appearing (there can be up to 30,000 viable seeds per head!)

- **Stem injection, cut and paint**

  Large woody weeds such as Castor Oil Bush can be injected with herbicide, or the plant cut down and the stump painted with herbicide. In very wet situations, stumps will weep for a prolonged time, and stem injection would be a preferred treatment.

- **Scalping**

  Very degraded sites with no native vegetation and a high weed seedbank in the surface soil may have the surface layer, containing the seed, removed or 'scalped'. The material removed can be mounded nearby so that treatment of weed germinants can be easily carried out on a compact area. This technique is not suitable for areas affected by flowing water or high groundwater levels. It is also important to ensure the original landform is not altered.

- **Smothering**

  Bare soil is very conducive to germination of weed seeds. Mulching using removed weed material or jute matting will suppress germination of seedlings and prevent seed from reaching the soil. Mulch should be carefully chosen to ensure it is free of weed seeds. It is also important to ensure the site is prepared correctly before laying mulch or matting by eradicating any weeds present on the site.

- **Herbicide**

  Large infestations of weeds and rhizomatous species are often treated with herbicide. Care needs to be taken with selection and application of herbicide, and this information is covered in the 'Herbicide usage near waterways' Water Note (Water and Rivers Commission, In Press). Frog breeding seasons should be avoided if possible.

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Further reading

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