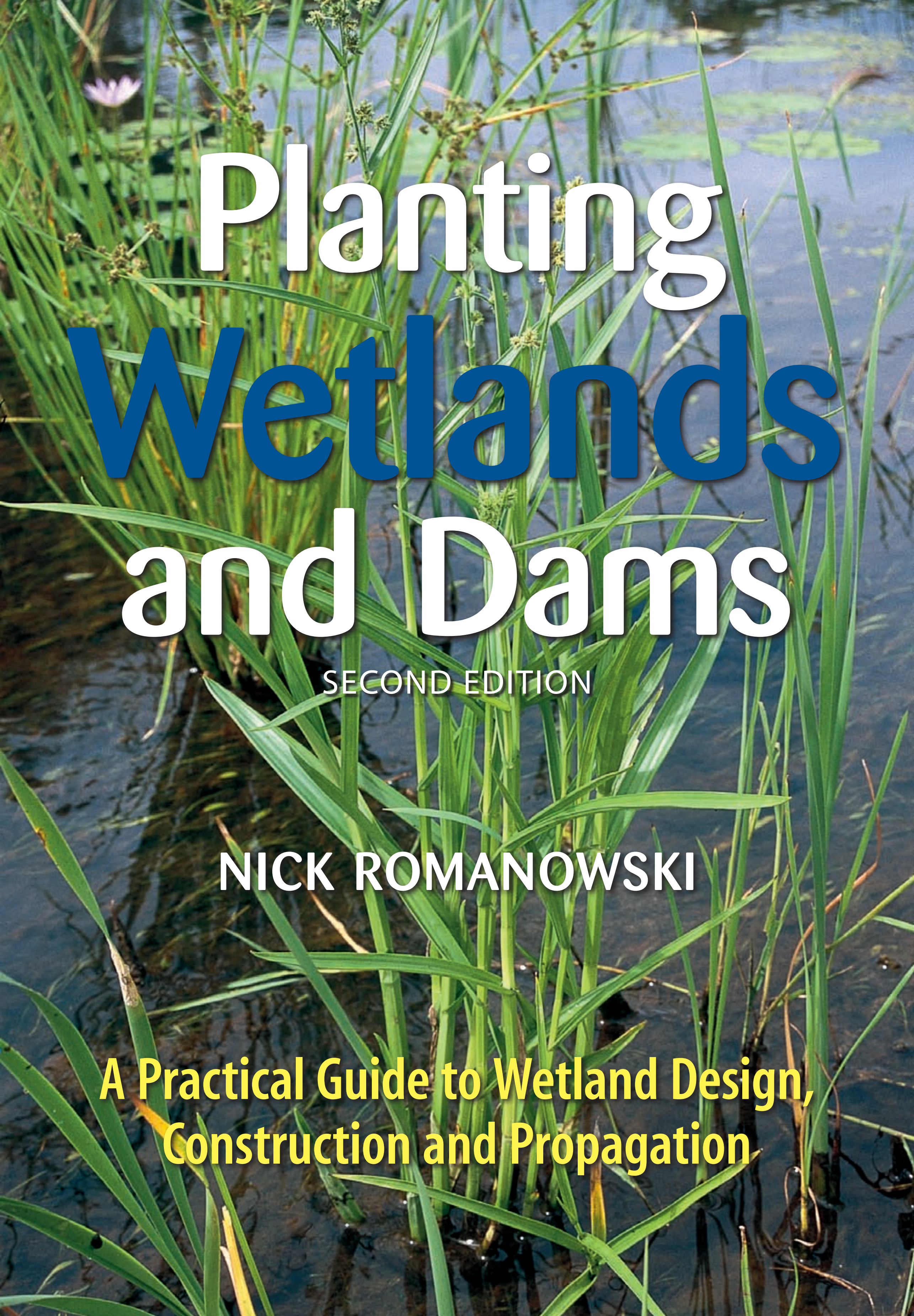

Planting Wetlands and Dams

SECOND EDITION

NICK ROMANOWSKI

A Practical Guide to Wetland Design, Construction and Propagation

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Front cover: Native sedges growing in a shallow stream, with *Fuirena umbellata* in the foreground.
Back cover: Constructed ornamental and water treatment wetland with water ribbons, paperbarks and several species of sedges (left); flowering water ribbon plant (right).
Title page: *Nymphaea pubescens*, an indigenous night-flowering waterlily.

All photographs are by the author.

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Introduction

This book is a summary of the plant-related aspects of my lifelong interest in wetlands, which began with an early interest in aquatic animals and their habitats, and led to working with plants as a major part of habitats over the past 30 or so years. Along the way, I set up the first nursery to specialise in Australian water and wetland plants, *Dragonfly Aquatics*. Much of the new practical information on plants included here has come from this, and from the many contacts I have made since that time.

My original intention with the first edition of this book was to produce a more complete guide to the practical aspects of wetland creation, restoration, and management, with an emphasis on the habitat requirements of wetland animals. It has taken 30 years before I have reached the stage where I feel I can provide useful answers and practical solutions to the many pressing problems and issues in wetland management, particularly in the context of climate change. This book is one of two (the companion volume *Wetland Habitats* is also to be published by Landlinks Press shortly), and I hope it will help to generate a greater awareness of our increasingly endangered wetlands in a time of accelerating change, and of the steps we can and should be taking to restore, replace, repair and replant wherever we can.

1
Wetlands

Living organisms don't just need water; by weight, every living organism *is* mostly water. Nearly all water on this planet is in the seas that cover most of the thin surface layer of rock we live upon. The heat of the Sun evaporates water from the sea, forming the rain-bearing clouds on which the lives of all land-dwellers depend. Rain brings water to the land, and the water flows mostly downwards as it returns to the seas, picking up minerals and other nutrients, and forming wetlands of many kinds as it goes.

It isn't easy to define just what a wetland is, and there are different definitions by hydrologists, legislators, engineers, biologists and ecologists. In the USA a whole job category called wetland delineators is required to even work out where wetlands begin and end! Some definitions are legal, some are practical, but the best ones are commonsense – wetlands are places where water forms pools or flows which last long enough that the lives of the plants and animals in these places revolve around its existence for a significant part of their year, or even life span.

Some wetlands are permanent, forming bodies of water which rarely disappear; others may flow just beneath the surface of the soil, rising and falling at different times of year and rainfall; still others may hold water for only a few months. Plants and animals found in the many types of wetlands are often adapted to extremes of flood and drought, but all need water for at least a part of their life cycle. Some may simply need water to quench their thirst, while others live in it for most of their lives and may only come out in the breeding season, and of course there are many which must have water for every stage of their existence.

Many wetland plants and animals are important even to surrounding terrestrial ecosystems, and the wetlands themselves recapture many nutrients and much soil which would otherwise wash out to sea and be lost to the land. There are theories which suggest that wetlands have been a forcing ground for parts of human evolution: these would go a long way to explaining some unusual aspects of our biology, and perhaps our preferred lifestyles as well. We are still drawn to water, and an estimated three-quarters of all human recreational activities take place in, on or near it – even an evening stroll is more pleasant near a creek or lake! The result of this urge to be near water is that towns with large wetland areas or water nearby draw tourists on a much larger scale than those without.

The role of wetlands in water-treatment is also being increasingly appreciated, even for such potent problems as human sewage. On private lands they can act as seasonal grazing, drought-proofing, and add to the selling value of the property. There are other obvious values – scientific, educational and aesthetic – that cannot be costed in dollar terms. And even these things may be minor compared to the long-term values of wetlands, which include ground-water recharge. We still know relatively little about the role wetlands play in maintaining the quality of underground flows, yet it is already obvious that much of the useful underground water in Australia will have been used up (as it already is in the USA), or else will be fouled beyond use within the next few decades if we continue to treat wetlands as waste dumps.

On our increasingly polluted planet, Australia has potentially the greatest claim to being among the last remaining sources of relatively pure, natural products, most of which depend directly or indirectly on the quality of our wetlands. Yet the sad fact is that on this driest of liveable continents we have put an incredible amount of effort into draining and destroying this precious resource; for example, at least one-third of all wetlands gone in Victoria, three-quarters around Sydney and on the Swan coastal plain around Perth, and nine-tenths in south-eastern South Australia.

The results have long been obvious. Stormwaters run off to sea more rapidly than ever before, carrying with them ever larger amounts of soil and nutrients. Floods are more serious, because most watercourses have been altered so much that flows are less controlled by the natural processes which used to regulate them, including their surrounding wetlands which acted as a buffer, delaying the passage of flood waters, and releasing them relatively slowly. The loss of our wetlands also endangers a substantial proportion of our fauna and flora, silts and pollutes rivers and underground waters, and has made Australia a bit drier, greyer and quite a bit less beautiful.

Increasing aridity associated with global warming is adding to the toll, as ephemeral wetlands dry out sooner, and droughts become increasingly frequent. There have been droughts lasting centuries in the past few millennia, and the aquatic biota has also had to shift and adapt as sea levels have risen 120 metres, flooding coastal wetlands that were refuges for aquatic creatures and plants at a time when inland areas were extremely arid. Many aquatics are excellent colonisers, spreading by wind-blown seed, or seed designed to tangle in the feathers of migratory birds, which are themselves nomadic.

These plants were able to shift inland, taking advantage of the increasing rainfall of the times, so it would seem that they are well adapted to change. However, the rules of the game have changed with the damage caused by European settlers. With fewer wetlands left, the distances between them are greater, so travel between wetlands has become increasingly difficult for plants, for frogs, and for many other species now found in ever more isolated and inbred pockets.

The damage can and must be undone if we are to salvage our fragile ecosystems, instead of continuing to follow the crude and ill-informed practices brought with the first European settlers. There are many steps which can be taken to bring wetlands back into closer contact, the first of which is recognising their increasing value and scarcity as global warming takes its toll, and wherever possible blocking the drains which have killed so many wetlands off.

If the drainage has been carried out fairly recently, especially in the past decade or two, seed reserves in the soil may bring back much of the flora originally found there, and in turn the flora will lure back many of the animals. But for most wetlands, the natural flora is long gone, and we need to replant – which is what this book is about.

Apart from restoring what we can of past wetlands, we should also be taking advantage of the huge numbers of farm dams which dot the landscape. Fenced and planted, these can offer refuges and resting places for animals, making the steps from one wetland to another all the shorter – instead of just providing a bit of muddy water for a few cows. Artificial wetlands of all kinds can be made to optimise habitat opportunities (though they rarely are!) as well as to improve downstream water quality.

Plants are integral to most of the things we can do to try to restore a balance, whether to hold the shoreline together against flood or wind, clean the water which passes through of both nutrient and sediment, and provide food and shelter for animals of all kinds. Unless you are a botanist, you will probably not be aware of how many types of wetland plants there are even on our arid continent, or of the diversity of the wetlands in which they are found. To use plants effectively, we need to understand the wetlands they are found in.

Plants and wetlands

There is a rich diversity of wetlands in Australia, from coastal-cliff waterfalls to swamps, rivers and springs, from deep lakes to roadside ditches which are dry for years at a time, becoming a crowded breeding ground in wet years. They are classified in many different ways by the various groups of people who study them, based around the way the water moves through the system, plant types, animal habitats, or other aspects. These classifications are usually designed as a framework for particular ways of studying wetlands, and can largely be ignored if you just want to appreciate their diversity, and the diversity of the plants and animals in them.

The variety of wetlands and their plants are briefly described here, but in reality many of these overlap, literally spilling one into another. A stream may slow down at obstacles and fan out to become a swamp, a swamp may disappear underground to feed springs below, a lake may feed a permanent river, or many different kinds of freshwater ecosystems may drain ultimately into a saline pool with just two or three resident species found in huge numbers.

Damplands and sumplands

Damplands are not usually seen as wetlands because much of their water is below the soil, sinking deep during drier seasons and rising to saturate the surface during wet seasons; the level of this underground water is called the watertable. Damplands are often acid and poor in nutrients, yet many support a diverse range of flowering plants including tea-trees, heaths, sedges from tiny creeping species to giant sawsedges, and other specialised plants from cordrushes and rushes to yellow-eyes. The shortage of some nutrients here (especially useable nitrogen) has been the cause of much specialisation among plants, even to extremes such as carnivorous plants which obtain some of their needs by trapping insects.

Plant matter doesn't break down rapidly in such nutrient poor, waterlogged soils, and often builds up very gradually as peat. Peat will hold large amounts of water for long periods of time, releasing it slowly into wetlands downstream even after the watertable has sunk far below the surface. For this reason, damplands of this kind (which are also known as heathlands) have a significant effect both on reducing flooding during periods of heavy rain, and in keeping up river and creek flow downstream during dry periods (see Colour Plate 1a). A dampland where the watertable rises above the soil level during the wet season, filling all depressions with water is sometimes called sumpland.

Ephemeral wetlands

Wetlands that fill directly from rain, and last only for a few weeks or months are usually referred to as ephemeral in Australia. The plants in them may die back to corms, rootstocks or soil seed banks until better conditions return. In short-season wetlands of this kind, many plants may be annuals that grow from seed as water levels rise, flowering and setting a new seed crop rapidly as the waters drain or evaporate away (see Colour Plate 1b).

The animals found in ephemeral wetlands may move elsewhere, or produce drought-tolerant eggs or cysts, and in many species the breeding animals themselves don't live more than one wet season. Others (particularly in arid inland areas) may burrow into the ground where they may survive for years while waiting for the next rains. Conditions like these seem harsh to us, but they have great advantages for suitably adapted organisms. Ephemeral wetlands may literally swarm with life for a time, and are free of most types of predator found in more permanent waters.

Spore, cyst and seed stages of plants and animals from ephemeral wetlands are often very small and lightweight, as they are designed to move as freely as possible between wetlands with wind, with waterbirds, or possibly even with insects in some cases. Arriving in a suitable place they will thrive, and even roadside ditches may harbour numerous planktonic species which first appeared as a single cyst. Ephemeral wetlands are also a further extension to the feeding grounds of many waterbirds and insects, which can visit during the wet season, and leave when conditions are no longer to their liking.

Fern gullies and springs

This assortment is not a part of anyone's wetland classification, but is my own way of grouping wetlands in which water moves fairly rapidly underground, sometimes coming to the surface. There is a practical reason for this grouping: moving water often carries a reasonable amount of oxygen even underground, so that plants which would drown in more stagnant conditions will thrive on slopes even though their soil may be completely waterlogged. This is probably why some ferns grow well on waterlogged, sloping sites, but are only seen on higher and drier ground around swamps where the water is not moving.

The types of plants found around springs vary considerably, depending partly on the nature of the water as this can be anything from soft and cold, to alkaline and hot. Completely different types of spring may even surface close together in some areas. The plants of fern gullies may also vary, but more because of variations in light than in the quality of the water, which is usually relatively free of salts. Tree-ferns and associated species dominate in shaded gullies among taller trees, while on brightly lit and permanently wet sites the dominant species are more likely to be coral ferns, water ferns and king ferns, with a canopy of melaleucas above.

Marshes and swamps

Extensive areas of still, reasonably permanent wetlands are generally called marshes or swamps. Their water levels may rise and fall to some degree between wet and dry seasons, but there is usually some water remaining near the surface. Marshes and swamps can spread over great distances in the wet season, especially on floodplains, and are of considerable importance as habitat in many ways.

There are no simple generalisations that can be made about marshes and swamps; they are remarkably diverse, and even other swamps nearby can be dramatically different in the plants and animals which predominate. In part, this could be because the first two or three plants to establish in a swamp may be able to prevent later arrivals from establishing themselves properly, and some animals are only found where certain plants are already established.

Marshes and swamps are among the hardest hit of wetlands in Australia today, and have been drained for agriculture, grazed by livestock, poisoned to control mosquitoes, not to mention being trampled by feral pigs. They are also among the types of wetlands which potentially can benefit most from good management and protection by individuals rather than governments, as many remain at least partly in private hands (see Colour Plate 2a).

Rivers, streams and creeks

Rivers, creeks and streams (brooks in Western Australia) should need no defining, although they vary considerably from cold, fast-flowing mountain streams to sluggish, warm and often muddy inland rivers. Theoretically, the management of such moving waters mostly falls under various types of government control, even including some of the surrounding land (see Colour Plate 2b). In practice, riverside vegetation is often managed or mismanaged by landowners and local government.

The worst forms of abuse are grazing and clearing, which expose riverbanks to erosion especially during flood periods, and contribute significantly to siltation and loss of water quality downstream. This also reduces habitat diversity and food supply for many animals adapted to waters running off cleaner and healthier catchments. Other abuses are less obvious, for example planting of willows along the banks in preference to indigenous vegetation, although the trend in recent years is increasingly towards willow removal.

Despite the work of various groups (not always with the same agenda!) carrying out and encouraging revegetation, the health of rivers, creeks and streams will ultimately only be improved by action through their whole catchment. And that is only likely to happen if State and Federal Governments register that we are still flushing away a large part of our natural wealth, and take real action to protect riversides instead of just enacting toothless legislation that is difficult to enforce.

Floodplains and billabongs

Rivers flowing through floodplains (particularly near the coast, and through much of the Murray–Darling system) tend to meander as they cut their way across. These often extensive plains of silt are deposited during periods of flood, which fill the various depressions in them to form swamps and pools. The most familiar name for these in Australia is billabong, a river bend that has been isolated from the main river flow when a new channel is cut. As it silts up at the openings leading to the new river channel, it becomes a still and often very beautiful pool that usually depends on floodwaters to refill it (see Colour Plate 3a).

Billabongs and other floodplain swamps are worlds in their own right, both a part of the river and separate from it. Their fauna and flora can be very rich, and may include species not often seen in other types of wetland. With the increasing control and regulation of many rivers, particularly the inland ones, it is likely that formation of new billabongs is becoming a rare event compared to what would have been happening in the past. At the same time, the disruption of natural flood regimes is killing off the species diversity of the old ones.

Until water for wetlands is regarded as a basic right (rather than being mostly directed to agriculture), billabongs and floodplain swamps are only likely to survive in a reasonably natural state with enlightened management, and then only if seasonal flooding can be arranged at least every few years. Yet water for maintaining wetlands is not given much of a priority, and one particularly large cotton farm pumps more water from the Darling River than is allocated to all environmental flows throughout the entire Murray–Darling catchment.

Lakes

Lakes vary considerably as they are formed in many ways; tarns scoured out by glaciers in the high country, volcanic craters, valleys dammed by lava flows or landslides, wide hollows behind sand dunes which accumulate organic matter until they hold water, and any other place where a large area of water accumulates for long periods of time. Their waters vary from nearly as pure as distilled water, through acid and peaty, clear and pure, or soupy with microscopic life, brackish to more salty than the sea. In our present era of increasing aridification, shallow lakes offer new opportunities to short-lived, colonising plants living a tenuous existence on their fringes, and which build up in huge numbers on the rich soils of their damp beds.

Living conditions in any body of water large enough to be called a lake will be very different to those in other types of wetland. As they are subject to strong winds and wave action, the vegetation around their fringes is limited to plants able to tolerate relatively rough conditions, and is often species-poor (see Colour Plate 3b). Lake-dwelling animals may also need to be tolerant of other extremes; for example in deeper lakes the upper and lower layers may have quite different conditions for most of the time, only mixing at the two times of the year when the surface and bottom layers equalise in temperature.

Saltmarshes, estuaries and mangroves

Saline wetlands have a distinctive flora, some of which is shared between salt-affected inland areas and the coast. By most definitions, wetlands end somewhere around the sea's edge, and at first glance these may seem rather bleak because of the absence of trees in southern areas. The trees and shrubs called mangroves become increasingly common and diverse the further north you travel. Below their feet in the low-tide zone the seagrasses begin, while behind there are often salt-tolerant herbfields called saltmarshes (see Colour Plate 4a).

Mangroves are largely found in estuaries, where sea and freshwater mix. The sea pushes in at high tide, rivers and creeks push the salt water back downstream as the tide falls. The mixing of fresh and salt water varies with flood and tide to give many different salinities at different times and places through the estuary, although in smooth conditions the less dense freshwaters may ride out to sea above the denser seawater below.

Little was known about revegetation and restoration of saltmarsh species until fairly recently, because there hasn't been much need, as the lands they occupy have rarely been seen as useful for agricultural purposes. This situation is changing rapidly as an increasing number of coastal saltmarshes are destroyed along with mangroves, to make room for development. The planting or revegetation of saline places will also become increasingly important as salinity problems associated with the last two centuries of B-grade land management continue to take their toll.

These areas are perhaps the most important feeding and nursery grounds for the young of diverse fishes and other marine animals, but they are rapidly being destroyed by developers anxious to make their fortunes from people who love the sea, and wish to live near it. It is a tragedy that by paying for the conversion of mangrove and estuary into housing estate, they are helping to destroy much of what they would like to preserve – clean water, good fishing, and the beauty of the coast.

Artificial and created wetlands

Farm dams and other artificial wetlands are potentially a considerable addition to our depleted natural wetlands. They represent a major increase in both area and types of habitat. With suitable modification they could certainly be made still more useful as an extension of natural wetlands. There are probably close to half a million farm dams in Australia, and any flight over drier areas will show that these are almost the only kind of open water available over immense landscapes. Many are in areas where there would normally be little or no permanent water, or where the artesian springs which once were the natural waters are now disappearing as a result of excessive pumping from bores.

Other types of artificial wetlands have only been constructed in any numbers in the past two decades or so, so there are still relatively few of these. Constructed (or created) wetlands represent not only an opportunity to try to recreate some types of natural waters, including our disappearing billabongs, but also to study the dynamics of wetland ecology in ways which are not possible in more passive types of research.

Dams and artificial wetlands could also have another role, though this seems poorly done at the present time. Those which can be kept free of introduced weeds and vermin could ultimately be used as (hopefully temporary) refuges for species which can't compete against the newcomers. For some endangered animals and plants, artificial waters may be the only real chance of survival they have left (see Colour Plate 4b).

It is not possible to duplicate the ecology of a natural area in a newly created wetland, and terrestrial soils are very different to those that develop over centuries underwater. Indeed, it is not possible to recreate most types of wetland at all with our present level of knowledge. However, a properly designed wetland should have the potential to *mature* into something very close to the real thing, and may even be indistinguishable within a few decades. Created wetlands are rarely intended to just imitate nature though, and many other values including water treatment, aesthetics and ease of access should also be considered in their design.

For some purposes, there may even be advantages to the creation of obviously artificial water bodies, rather than recreation of the problems facing damaged wetlands today. Whatever the purpose of a created wetland, the commonsense approach to design and planting should use species which occur naturally in the area, using comparable, un-degraded, local wetland communities as models. Such places have evolved with – and are already adapted to – the challenges of climate and season, and are much more likely to survive the increasing aridity changing the face of much of Australia.

2

Planning a dam or wetland

Most wetlands and many dams are created for a variety of purposes. These should be clear in the designer's mind before plans are even begun, as they are not necessarily all compatible or easily achieved in a single body of water. One commonly cited purpose is to create habitat for the varied and endlessly fascinating plants and animals found around water, yet most created wetlands in Australia are treated as an exercise in landscaping instead. No one expects to recreate a forest ecosystem with an artificial planting, but many would-be wetland designers believe that they are recreating ecologies even if they have little knowledge of the component parts.

Other and more readily achievable goals include provision of water for stock, improvement of water quality through planting, and often just the creation of an aesthetically pleasing environment for fishing, swimming and aquaculture. These goals can easily clash; stock has the opposite effect on water quality to planting, while aquaculture and habitat values can only be married in a limited way.

A further problem with the current notions of dam or wetland planning is that there is rarely any assessment made of whether a created wetland does what it was supposed to do. Proper planning should also allow for recording of results, whether these come out as expected or not. This will not only help in creating more predictable and easily managed wetlands later, but can even add to our understanding of the ways natural systems work. This chapter outlines the general ideas behind planning, including related areas such as modification of existing dams to make them more like natural waters.

What are your goals?

Planning is largely a matter of commonsense, and it is usually possible to blend various goals in one wetland, although some may have to be modified. Choose one or two primary goals that are central to your interests, and then consider if there are any others that might be compatible. It usually doesn't take more than a few minutes to see where problems may set in. For example, swimming may combine well with some types of aquaculture, but not with stock access for watering. By contrast, good fishing can be had even with some stock watering, but is not compatible with most habitat requirements unless no hooks or nets are likely to be lost where animals can swallow them, or become entangled.

Appearance is always important in wetland design, particularly maintaining enough areas where open water can be seen from the shore. This is sometimes done by using only very low-growing plants in the shallows, but the resulting effect is both artificial and has limited habitat value. It is more effective to combine a greater diversity of plant species with varied underwater planting depths to give a more natural-looking shoreline.

Irrigation from a wetland is not compatible with most other goals, unless the wetland area is very large and the volume of water to be taken is very small. The water in natural wetlands drops through evaporation or lowered watertables over the warmer months, but if you add irrigation drawdowns to natural falls, many wetland species will not be able to complete their biological cycles in the reduced time available. If you want irrigation water *and* a wetland, it is best to create a water storage dam upstream/uphill of the wetland; this can also be used to top up the wetland if required. However, a wetland extending a dam is a different matter, and this is considered separately later.

One general recommendation can be made for most types of created wetland – make them as large as you can within the space you have available and the limitations of your budget. Cost is often a factor for extensive works as earthmoving is expensive, but the cost can be spread over a number of years when you create a series of wetlands. If these are to be linked, make allowance for joining each one to established areas, in such a way that new work doesn't suddenly drop the water level. A further advantage of gradual extension is that you can transplant thinnings and seed from earlier plantings to new areas as they are constructed.

Readers of this book will probably already be committed to the idea of creating or restoring a wetland, but with the increasing aridity of many Australian climates, a question that *should* be asked is whether a new wetland is actually appropriate! Improvement of downstream water quality may be better served by using waste waters to irrigate plantations or vegetables, rather than crudely purifying them through plant beds before release into other wetlands or streams, which are already suffering deteriorating water quality through reduced flows.

Over the past decade, wetlands have become a fashionable accessory in new housing estates, where the prime real estate overlooks the water. All too often, especially in inland areas, these 'water features' were dependent on unlimited supplies of water to be pumped from rivers and reservoirs (see Colour Plate 5a). Many of them now stand dry, with not enough rainfall to fill them in the winter and spring. Apart from the barren appearance of these cracked claypans, they also now act as evaporation basins that reduce the increasingly limited flow into natural wetlands and rivers still further.

Regulations and permits

Laws and permits affecting the construction and restoration of wetlands vary considerably from State to State, and any attempt to summarise the current situation for all of Australia would require a book in itself. Construction of new dams in particular is now rigorously controlled in many areas, though repairs and modifications of existing dams may not require a permit at all. It isn't difficult to give a general idea of who to approach for information, to lead you through the legal problems potentially associated with work of this kind.

A new wetland is least likely to need elaborate paperwork in rural areas, or at least no more than would usually be associated with sinking a dam. The local Shire or Council may make all decisions of this kind, and will put you on to any other regulatory body with a veto on new work. In some rural areas you may still be given permission to go ahead with some types of dam just through a phone call, but make sure you get this confirmed in writing before any work begins! Any unexpected restrictions or hitches are most likely to be discovered if the contact person has to check up on their facts, before committing themselves to writing.

There will be limitations on what can be done if neighbours will be affected, particularly where a dam or a re-plugged wetland may bank water up so that it overflows onto another property. This is obviously unacceptable unless the neighbour is keen to share in the new wetland. Permanently flowing waters cannot be dammed without permission, as these are usually regarded as a public asset rather than a private one, and there may also be specialised safety considerations for water-retaining embankments in such cases.

Potential effects on any kind of indigenous vegetation already present must also be considered, and in some States it can be an offence to deliberately or accidentally drown other vegetation types. In any case, it should be obvious to anyone wanting to create new habitat for compatible vegetation that this type of damage is environmental vandalism.

For all these reasons, the future boundaries of any new wetland must be fully surveyed with a level before plans are finalised. If no problems are found, and the water running out of the new wetland will be at least of the same quality as what is running in, then usually no other permits are needed. Of course, if the water running out of the wetland is not improved in quality on its way through, something is seriously wrong with the design, or the situation.

If the planned work involves modification or restoration of an existing wetland, there will often be more complicated procedures to go through. There are good reasons for not allowing random alteration of even the most weed-infested and degraded wetland. For example, valuable remnant populations of less common plants may still be present, even if these are largely swamped by weeds and unable to grow or reproduce properly. Any alterations made should include a management plan for such remnants, giving them the best chance to recover as a result of the changes.

Extending existing wetlands requires even more care and thought, because this invariably shifts wetland boundaries and alters flooding regimes. All wetland plants have definite preferences as to depth, so raising water levels too rapidly and too much will drown those which are unable to adapt fast enough. A very gradual increase over many years will allow most wetland plants to shift with the new levels, whether directly through runners, or indirectly as their seed germinates at higher levels. However, plants that cannot spread by runners or can only set a small quantity of seed may be unable to colonise areas where other species are already entrenched, and would need transplanting which is not reliably successful.

Most works that will affect existing vegetation are regulated by State laws, rather than by local ones. They are administered by whichever authority protects native fauna and flora in your State, although if you plan to introduce fishes there will be fisheries laws to comply with as well. Check all such laws through your regional State Government offices. It is rarely difficult to find the person best able to tell you which laws will be relevant, and whether there is any other State office (usually in the same building) you may need to make contact with.

In more built-up and urban areas, there is a much greater need for following up all laws and permits that could possibly affect the planned work. The reasons are obvious and may include neighbours who are likely to be closer, existing plant communities which are more likely to be under pressure from weed competition, and the safety of dam walls and embankments, which becomes increasingly critical. Contact with local government remains the first step to finding what legal constraints there may be, including related information as to the possible presence of underground lines and pipes, and who has put them there.

After overcoming any complexities of wetland construction and restoration, you may also need to apply for a permit to collect seed, cuttings or divisions of plants for propagation, if these are to be taken from public land. Such permits are also managed by State and Territory Governments. Collecting from private properties can usually be done with just the owner's permission, but there are sometimes restrictions on which types of plant can be gathered even here. Some indigenous nurseries with all the required paperwork and local knowledge will propagate locally sourced wetland plants to order, but this usually needs a lead time of anything from four months to a year to allow for collection and growing time.

If you are propagating any of your own plants from material collected from public land, there is usually a requirement to keep records of what has been harvested, and in what quantity. It would be better still to keep records of how these plants establish and grow as well. If possible, use photography to document the changes every few years as wetland planting is, relatively speaking, still in its infancy, and the more records are kept, the more information exchanged, the sooner creation and restoration of wetlands is likely to become a predictable science.

Choosing sites

The two most important factors in creating most types of wetlands are cost-effectiveness (area created per dollar spent) and natural appearance. There is no conflict between the two; the least expensive, most natural-looking wetlands are on relatively flat land with some slight undulation and variation. The less earthmoving the better, so islands, peninsulas and underwater planting shelves or plateaus should follow existing contours as closely as possible. On the minus side, such sites may already have wet or boggy patches with established plants, and if any of these are unwanted species they will need to be controlled, both plant and seed, before the wetland is flooded.

Some low-lying sites may also be unsuitable as homes for smaller native fishes and frogs, many of which have been considerably reduced in numbers through competition with plague minnow (*Gambusia holbrooki*). This aggressive little fish was introduced to control mosquito larvae, a job which it doesn't do any better than native fishes. It is now very widespread, and will frequently arrive in new areas with flood waters. So will carp (*Cyprinus carpio*), various tilapias and other unwanted fishes that can be very destructive of submerged vegetation.

To keep vermin fishes out, earth banks (levees) should be constructed around low-lying wetlands, engineered to hold off even the highest flood waters. Levees are usually designed to cope with lesser degrees of flooding; 20 or 50-year events are commonly specified. However, even one breach of the embankment in 20 or 50 years will bring in unwanted fishes, which are often difficult to eradicate without completely draining the system. If it is not possible to build up a higher levee, a more elevated site may be preferable if the wetland is intended to provide satisfactory fish or frog habitat.

Wherever the wetland is sited, it is likely to bank water up into areas that would normally have been drier. This increased flooding can kill plants which aren't adapted to wet feet, and even water's edge species won't all survive an extra month or two added on to their average wet period indefinitely. Commonly seen examples of this problem include redgum or melaleuca stands that have died gradually because of permanent rises in water level, sometimes even quite small ones.

The water source for the wetland is usually either run-off water that is collected in a water-retaining basin, or an underground watertable that rises and falls with the seasons. Wetlands made to hold the water that runs into them should be constructed in the same way as a properly made farm dam or – like an estimated one in three farm dams – they will leak. The area of such wetlands will partly be dependent on the amount of run-off water flowing in from upstream, as there is no point creating a large wetland area that doesn't have enough catchment above to fill it in an average year of rainfall.

It isn't always easy to work out how much water will be available; this depends on when the rain falls and over how long a period, how much water the soil will absorb before further rainfall begins to run off, and evaporation rates. If you are in any doubt that the catchment is adequate for your plans, then your plans are probably too ambitious. However, it may be possible to increase the catchment area with shallow drains fanning outwards to collect run-off water from a greater area than would normally be available, during times of heavy rains.

Wetlands should not be dug into an existing watertable if you are not sure how much it will rise and fall with the seasons; this can be worked out by using an earth auger to dig a test bore. Even a hand-driven 10 cm auger can be used for this, and can be extended up to 3 metres if necessary, with additional pipe sections of the same thread as you go deeper. If the watertable is found to vary regularly by a metre or more, there will be problems with establishing water plants, just as in irrigation dams.

Where underground water surfaces from a spring, it is best to avoid disturbance as this can alter flow rates, or even stop the flow altogether. In extreme cases where a spring enters at a level below the planned water level, water may even channel back out through the spring so that the dam or wetland never fills. Some very deep artificial pools and dams are spring-fed, but usually have the spring at the side of the pool or slightly above it, so that it is minimally disturbed by digging.

Although relatively flat or gently undulating land is the easiest and least expensive place to build substantial areas of wetland, not everyone has a site like this. The greater the slope of a site, the less likely there is to be any underground watertable that can usefully be tapped into. On sloping sites the most common option is likely to be a wetland built like a dam, using a water-retaining wall. Extensive wetland areas are impractical in such situations, but a series of smaller wetlands descending from one to the next may be possible, although relatively expensive for the volume of water they will hold.

Where there is room for only a single wetland on a relatively steep site, it will be deep compared to the surface area, with a substantial retaining wall – in fact, it will be very much like a dam. There is nothing wrong with this assuming that you can afford it; well-designed dams can be used in various ways to create a range of habitats. However, the deep waters and steep sides of walls and islands in a dam are often incompatible with the types of plants seen in broad, shallow wetlands, and may be undercut along their shorelines by waves and dabbling ducks.

Sites with excessively saline groundwater should be avoided. Although there are a few plants which will grow and even thrive in very brackish water, there are relatively few animal species which are as tolerant. This means that saline waters are more likely to build up large populations of midges and mosquitoes, the larvae of which would be eaten by a range of predators in fresher waters. On the positive side, a moderate degree of salinity may be an advantage in dispersive clays, as it will help to bind clay particles together so that retaining walls hold water more reliably.

Salinity is a more subtle threat in dams and wetlands filled by run-off, especially in drier climates. The run-off water may only be moderately saline, but the salinity in the wetland will increase in warmer seasons as evaporation concentrates the salts. If such dams and wetlands are not adequately flushed by freshwater run-off from winter rains, their salinity will continue to increase from year to year.

Other considerations

Depending on the uses you intend for your wetland, you may need to plan for reserve water supplies, structures extending out over water, islands of various kinds, a varied underwater landscape, allow for overflow in flood times, remove excessive sediments from incoming water or make provision for drawdown of water levels. Drawdown and overflow structures are discussed in Chapter 3 under water control; the other aspects are considered here.

Structures that project out over water should have at least their footings in place before the wetland fills, which often means within a few weeks of completing the earthworks. Walking ramps can be constructed on established footings even after water levels rise, but for more elaborate structures such as jetties and hides, the supporting frame or scaffolding should already be in place before flooding.

Ramps may be built over any range of water depths or wet soils, but jetties and hides should be placed so that they finish well out from the shallowest water, whether they are used for fishing, swimming, or observation. It is all too common to see a hide that doesn't extend beyond the shallows, with a screen of reeds or rushes in the foreground obscuring more distant views. Hides are intended to give a good view of birds and their behaviours, and although plants can be cleared out of the way regularly, disturbance will make the nearby shallows less attractive to waterbirds. Viewing windows at the sides of the hide are a more appropriate place to observe nesting areas, as plants can be allowed to spread here as they see fit.

Jetties are a very different type of observation area, often sitting lower to the water, and allowing better viewing of underwater animals, including fishes. They cut down on reflection which can screen much of what is below the surface from the shore, but which is reduced considerably if you are looking more-or-less straight down. Fishes, in particular, are less wary near jetties because, from their point of view, the platform you stand on looks like a deeply shaded, overhanging ledge under which they can easily take cover.

Other uses for jetties include as a working area right next to the water, as a place to fish from or to hang aquaculture cages under, and of course they are a great place to hang a hammock. There are many other ways in which they can be adapted, for example designed so that temporary screening walls can be clipped into place to make a bird hide during breeding season. A permanent canopy to keep rain and sun off is highly recommended, and can make the jetty into an exceptionally comfortable outdoor living area during the heat of summer.

Barriers may be needed to keep livestock or humans out of sensitive zones such as breeding and nesting areas. Humans are easily put off by strategic barriers such as shallow water and very boggy soils, or more obvious obstacles such as sedges with sharp-edged leaves. Cattle will push through either of these, and will need to be kept out with conventional stock fencing.

Stock can sometimes be run in wetland situations without excessive damage, and may even have their uses as a management tool for short periods of time, but will reduce plant diversity especially in small areas. A fenced wetland can still be used to water stock by pumping or siphoning to a trough, or by including a fenced-off ramp lined with coarse gravel to control their access to the wetland.

Cattle manure in moderate amounts is a useful source of nutrients for both plants and plankton, but they also erode the sides and fill deeper areas with the resulting sediments, and their constant presence may encourage a build-up of liver flukes or other parasites. There is abundant evidence that cattle drinking piped water (free of parasites) from troughs may grow up to 40% faster than those drinking direct from a wetland or dam which they have contaminated with their own wastes – a good economic argument for keeping livestock out of the water.

Livestock are not the only source of sediments in wetlands. Even average rains can cause problems if the soil upstream is exposed to erosion, especially after ploughing, and shallow wetlands can silt up very rapidly. Incoming water should first pass through some kind of silt trap, where its velocity is reduced enough that a large part of the silt will have a chance to settle out. Silt traps are relatively small and more readily accessible than the main water body, so they can be cleaned out less expensively than the wetland itself.

A small, relatively shallow settling dam above the wetland is adequate in many cases, but there are also many more elaborate designs depending on expected flow rates, and how tightly incoming water can be channelled. Local soil conservation authorities and Landcare groups should be able to give advice on what is most suited to your area and conditions. Unfortunately, silt traps are not very useful when they are needed most – during flood periods, so even the best planned wetland will gradually silt up just as natural ones do.

At other times of the year, water may be in short supply, and the wetland will dry out. If planted and designed along the lines of natural wetlands, this is no problem as it is a part of the annual cycle. There can even be advantages to cyclic rises and falls in water level, including the control of some types of plant growth in the shallows. Wading birds will also have access to exposed, drying mud as water levels drop, and this is an important foraging zone for them.

If you want to maintain the water level around maximum at all times for the sake of appearance (and for faster plant growth), a reserve water supply somewhere upstream or within easy pumping distance will be needed. This should hold *at least* enough water to top up evaporation losses in the wetland in a low rainfall year, plus allow for evaporation losses from the reserve itself. However, the potential salinity concentration problems mentioned earlier apply to water reservoirs as much as to the wetland itself.

Islands are usually carved into the wetland soils, but if the slope is too steep to make this economical, a raft in the form of a floating island may be used. I have yet to see a satisfactory, natural-looking design for these, and they don't seem to appeal much to birds, except as an elaborate and expensive resting spot. Floating islands need to be anchored against wind and current movement to keep them from running aground. If they sink, rougher ones can become a menace to swimmers and diving birds, although they will provide shelter for some underwater animals.

Floats used for such islands must be corrosion proof; and even 44-gallon drums will last for decades if they are dried inside and out, painted liberally with swimming pool paint, and then properly sealed. Wide diameter PVC pipes (sealed at all joins and ends) are expensive, but easier to use as they need no pre-treatment and can be more uniformly arranged beneath the island to float it without tilting. Less waterproof materials such as foam boxes won't hold an island up for long, as they become waterlogged and lose flotation after a few years.

If plants are to be grown on a floating island, it should hold a soil layer around 5 to 10 cm deep, the lowest part of this being underwater so that the soil remains wet at all times. Weigh a *wet* soil sample of known size to estimate how much extra weight it will add to the island – don't work from dry weight or your island may sink as soon as it is wetted! Soil is best shovelled on and wetted once the island is already afloat, but if this isn't possible keep the soil dry until the island is launched, as wetting can double its weight. For islands with the top substantially above water, a gently sloped ramp may be needed for waterbird access to the top or it may not be used at all.

Islands made of earth are more attractive, but are often made so that they look like a miniature volcano protruding above water. As most waterbirds do not like struggling up steep slopes, islands should be flattened just above maximum water level, or can be shaved to a little below the water surface for species that prefer to build raised nests in shallow waters. If the underwater slopes of the island are steep, a gentler landing ramp should be cut in along at least one side.

Such ramps often form a shallow bay cut into the centre of the island, creating a horseshoe shape – particularly recommended for larger islands, as reports from the USA indicate that foxes may make their nest burrows in the drier soils at the centre of these, and an inlet will help to keep the centre wetter. The extended curve of horseshoe-shaped islands also seems to separate potential breeding sites in the eyes of some birds, so more pairs may be willing to breed relatively close together, as they may feel less crowded nesting on opposite arms of the bay.

In extensive shallow wetlands, piles of unwanted timber, stumps and rocks can be heaped to form small and inexpensive islands, though these can be an eyesore if the materials are too obviously unnatural – for example, those sporting numerous chainsaw cuts. Timber is not suitable for deeper waters as it will drift before sinking in random places. Other, relatively wholesome detritus such as spoiled hay can be added over the years to such islands in *moderate* amounts, boosting populations of smaller invertebrates as it decays, attracting more birds and indirectly increasing populations of many other aquatic animals.

The underwater landscape should be planned in advance, including planting shelves and plateaus that will be submerged later, though smaller planting pockets and narrow shelves can be made with hand tools even after flooding. If an open view across water is desired from some places, the shoreline should drop quickly into relatively deep water, planting shelves should be narrow, and lower-growing plants should be used. For extensive stands of reeds and rushes elsewhere, make their underwater plateaus broad.

Shelves, plateaus and pockets can also be used as a management tool, for example to keep more invasive plants to one area only – assuming that these don't spread by seed too readily. These shallow areas should be at the appropriate depth for the plants selected, allowing for 5 to 10 cm of prepared soil to go on top, plus a layer of coarse sand or fine gravel if this is needed to keep the soil in place. On very gentle slopes that are not exposed to much wave action, constructed shelves are not necessarily needed as there will be a range of depths already available.

Wind, erosion and surrounding vegetation

Many wetlands are wide open as well as flat, so wind can build up considerable velocity over them and generate substantial waves. These cause two types of problems. First, they limit the variety of plants that can be grown in some areas.

Second, they can cause massive erosion particularly along retaining walls, and may ultimately destroy the wall itself. Wave action can be reduced by the strategic placement of islands, shallow areas and breakwaters.

Large, open expanses of water don't provide as much useful habitat or water treatment area as a series of smaller ponds, or a large wetland broken up by underwater ridges near the surface so that plants can form wind breaks and wave-breaks along them. Reeds, sedges and other taller plants will help reduce the momentum of wind across the water's surface, but may increase water loss to the air as some species suck water up even faster than evaporation does. If the wetland is broken into many smaller linked ones, taller windbreaks can be planted between and around the ponds, above the limits of wetland vegetation. However, these should be shrubby plants such as teatrees or paperbarks rather than trees, as tall timber is not often found close to the edge of swamps.

Belts of terrestrial vegetation surrounding the wetland, at a moderate distance, reduce sediment run-off from surrounding land and help absorb excessive nutrients and contaminants that can cause water quality problems. A further benefit is reduction of noise and screening of movement, for example from nearby traffic or farm machinery that may disturb breeding wetland animals. Vegetation belts used as screens around a wetland may need wide gaps in them so that birds can see their way to fly in, especially if the water area is small; these are called flight paths.

Trees and larger shrubs should not be planted along retaining walls, partly because they may blow over in high winds, tearing part of the wall out with them. Their roots may also push through the retaining wall in search of water, creating a seepage line that will eventually breach the wall. Dead roots do even more damage as they may eventually rot away to leave a pipeline for water to flow along, so even smaller shrubs can be a problem for this reason. If you intend to plant along the retaining wall, choose species that prefer drier conditions so their roots are not tempted to stray towards the wetter zones.

Orientation of a wetland to prevailing winds is important. In coastal southern Australia wetlands open to the south are most affected by south-westerlies, which can reach gale force at times, though northerlies may become increasingly prevalent as global warming takes its toll. Towards the tropics, winds are more seasonal blowing from different directions during monsoons, and during the dry season.

High, open sites are the most difficult to deal with because they may be affected by wind turbulence as well as direction. Regardless of direction, strong winds generate waves. The longer the distance these have to build up in, the higher and more destructive they will be, so the long axis of any open water area should be across the prevailing wind direction, and not along it.

If it is too late to do anything about the site of a dam or wetland, a series of breakwaters may be used to absorb wave energy, so that these do not build up too much momentum. These are basically structures which redirect wave energy into the *floor* of the wetland. As most wave energy is concentrated in the top metre or so in inland waters, the solid part the waves hit does not need to be much deeper than this, but allow for evaporation losses in summer as well. Breakwaters must be firmly braced against wave direction, so the energy of waves hitting them is transmitted into the floor of the wetland through a downward-angled brace behind. Floating baffles won't work, however securely they may be anchored, as they just move with the waves and absorb little of their energy.

Exposed shorelines will also need protection against wave action, in the form of solid barriers of rock or concrete. However, there will still be considerable turbulence behind any such barrier if waves break over it, and a layer of coarse gravel over the planting soil will reduce washing out. The combination of waves and gravel limits the choice of plants in such situations to taller and more vigorous species, those already adapted to strong currents and disturbance.

If the wetland is still in the planning stage, it may be possible to weaken the impact of waves by having a shallow area (rather like a sandbar) a bit further out from the shore. This should be held together by rocks large enough that they won't be shifted by the expected wave energies. Breaking waves over such 'rockbars' can be quite dramatic in appearance, but much of their energy is lost here. The resulting reduction of impact energies at the water's edge means that finer gravels or coarse sand can be used on the surface of the planting beds, and allows more choice in planting.

One form of erosion rarely planned for is burrowing, the two most common culprits being freshwater crayfish (particularly *Cherax* species) and water rats. If there are natural wetlands nearby with either of these, they will inevitably turn up sooner or later. There is little point in trying to keep them out; after all, what is habitat for, if not for these and similar creatures? Just make sure their energies are directed away from critical areas, particularly retaining walls where burrows could cause structural problems.

If you expect such immigrants, layers of shadecloth or other strong, fine meshes buried a little under the surface will stop them from burrowing, and will last indefinitely protected from sunlight in this way. If crayfish are likely to be the only problem, a gentle gradient no more than one in four on retaining walls discourages digging, as they prefer steeper overhangs for their burrows. Crayfish are also less likely to burrow in wetlands where water levels don't vary much, although they will still cause some minor damage around the waterline.

Habitat

Many of the design considerations already looked at are directly related to the habitat needs of wetland animals, but the *idea* of habitat should be considered in its own right. All too often, a wetland is imagined to be a successful habitat regardless of what is in it, or what was intended to be in it. This is particularly clear on sites where black ducks (*Anas superciliosa*) are sometimes seen, but little else. These birds are often cited as evidence that a wetland is a successful habitat, however poorly it may have turned out in reality.

If black ducks are treated seriously as an indicator of wetland quality, then even a muddy, unplanted farm dam would have to count as successful habitat. This bird is a widespread, migratory opportunist; it is even found in large numbers in municipal lakes, apparently thriving on a diet consisting mainly of white bread! When conditions are no longer to their liking, black ducks simply move on, an option that is not available to many other wetland animals.

A wetland habitat should be designed to meet the needs of *specific* target species, whether this is one animal or several compatible ones. Only then can it be seen whether it has been successful or if it has failed. Designers often seem afraid to spell out specific habitat goals, yet well-documented wetlands that don't end up as planned can still add to our understanding of what we are doing. And a well-designed 'failure' may provide unexpected opportunities for other animals to move in, which will also add to our knowledge of *their* needs if everything has been documented.

Each different animal has a different set of requirements which must be met if a wetland is to provide complete and adequate habitat for it. Wetland animals are diverse, so it is obvious that no sweeping generalisations can be made about what is and what is not desirable in a design. The first step in planning for any particular species must be to learn as much as possible about its life, habits, diet and preferences, from all sources available as these may sometimes contradict each other in details. These and many other issues are looked at in much greater detail in a companion volume, *Wetland Habitats* (also published by Landlinks Press, available in 2010).

The common snake-neck turtle (*Chelodina longicollis*) is a good example of a species that is apparently thriving in some wetlands, yet may often be in an ecological dead-end. It is a long-lived animal, probably living for many decades, and substantial populations are found in many inland waters of south-eastern Australia. A closer look at these often shows mostly mature animals, and very few young ones. One survey of the breeding sites of this species has found that up to 97% of nests in the study area were dug up and destroyed by predators, mainly foxes, suggesting that young tortoises must be *much* less common than before European settlement.

Turtle habitat must therefore include breeding areas secure from foxes, and well above the highest flood level as a site which they have seen flooded is unlikely to ever be used for nesting again. Their preferred nest sites are usually sunny places with reasonably soft or sandy soil a fair way up from water, and often a surprisingly long way inland. If females are disturbed while trying to dig a nest they may end up laying in water (where the eggs drown), but fox-proof fencing will minimise disturbance of all kinds.

Fortunately, the other habitat requirements for snake-neck turtles are modest. They will hibernate in or out of water, and feed happily on the introduced plague minnow, a fish that has caused much havoc among native fishes and frogs. As long as adequate nesting sites are provided, it is likely that these turtles will thrive and even multiply in created wetlands. Providing appropriate habitat for many other animals may be just as simple, if we take the trouble to familiarise ourselves with their life cycles and needs.

Modifying existing dams

If you already have dams on your property, they will usually have been made to hold water for stock or for irrigation, and you may want to keep using them for the same purposes. There are many steps you can take to improve the value of such dams as habitat for a wider variety of plants and animals. Whatever changes you may decide to make, avoid tampering with the basic structure of a successful dam wall – it is all too easy to create leaks and weaknesses where there were none before.

If you keep livestock of any kind, one simple improvement is to fence them out, which will allow you to plant around and in the dam. Complete fencing is easiest to arrange, assuming that a siphon line or a windmill can be set up to fill a drinking trough nearby. Fencing stock out from even a part of the dam will improve water quality, and if you close off access to the retaining wall this will last much longer. However, it is possible to manage stock in wetlands with adequate results under some conditions, particularly if you aim to maintain a diversity of invertebrates in more ephemeral waters. Many of these smaller creatures will thrive where livestock keep vegetation down, and will benefit from the resulting fertilisation by manure.

Existing islands and peninsulas that are too steeply sloped for waterbirds should be levelled to just above the highest water level. This can be done by a bulldozer if a shallow and not-too-mushy access area is available, or by an excavator if the island is not too far from shore. Hand tools do the neatest job, and should be used to trim up after machinery; if they can be used for the whole job, it will also be easier to leave any existing patches of vegetation unharmed.

Steep-sided islands and peninsulas are usually also steep underwater, and submerged terraces around them to retain the soil chipped off the top of the island are a useful way of increasing planting area. Extended shallows created this way also make access to shore easier for waterbirds and reptiles. Terrace walls which stop soil sliding off into deeper water can be made from old lumber, which can be very long-lasting underwater, or with larger rocks and waterlogged tree-trunks. If timber is held in place by star posts, the tops of these should be hammered until rounded as they are otherwise dangerously sharp.

Planting shelves can also be made within an existing dam by a backhoe or an excavator even when the dam is full. However, these shelves must never be dug into water-retaining walls. Perhaps the most dramatic improvement you can make to an existing dam is to add an extensive shallow planting area along one side, to form a new wetland in its own right. If appropriately planned, this can encourage a range of new arrivals – from nesting birds to smaller underwater animals.

Such additions should slope gently down towards the dam itself, although they can also be fashioned into a sort of artificial billabong adjoining the dam, and only connected to it during times of the highest water levels. A shallow, graded area like this will allow a wider variety of plants to grow than the steeper sides of the dam itself. The beauty of a properly designed combination of new wetland and old dam is that you can use the dam much as before, including for irrigation, which is usually only needed once most water animals and birds using the wetland have already completed their natural breeding cycles.

The dam will fill with seasonal rains, overflowing into the wetland and triggering plant growth and animal breeding just as in comparable natural wetlands in the area. Once run-off stops, evaporation begins, slowly at first but accelerating as the sun develops a bit more bite. By carefully choosing the depth of the new wetland sloping to the dam, you can decide approximately when the new area will become completely dry, by which stage the dam will have retreated back into its original area again. For example, if evaporation in shallow wetlands in your area will draw off about 15 cm of water within nine weeks of rains finishing, and you need to start irrigating at about that time, then the deepest part of the new wetland extension should be about 15 cm deep.

Using the same example, if you plan to start irrigating at six weeks the extension should be about 10 cm deep at the most; if you won't need to irrigate until 12 weeks, it can be up to 20 cm deep. These depths should be measured from the top of the soil layer, and not from the bare clay it rests upon. Although the extra surface area added by the wetland will increase the *total* evaporation loss, *all* of the extra loss will come entirely out of the surface area of the extension. Remember that the dam would usually have lost the same amount of water through evaporation in the same time, regardless of whether an additional habitat area has been built on behind.

Use natural wetlands in your area, of the same depth, as a guide to planting. A wetland dominated by rushes which usually grow where they are high and dry within a month will not attract nesting birds which need water around their nests for two or three months. However, it will attract those that forage over drying mud, and even if their nests are somewhere else in some other wetland, you will have increased the total amount of habitat available to them. On the other hand, a wetland area dominated by plants that grow mainly where water will stand for many months gives different signals to potential breeders – they will recognise suitable breeding habitat at a glance.

Water treatment wetlands

Wetlands are not a miracle cure for wastes running off surrounding lands, but they certainly help to improve the quality of water moving through them. This is partly done through the action of micro-organisms in the substrate and on the surface of the plants, and partly through luxury uptake of nutrients by plants. A complete discussion of water treatment is far beyond the scope of this book, but a brief outline of design considerations for this purpose is useful.

Although many different water treatment designs have been used worldwide, it is notable that even now none of these have proven to be so far ahead of the others that they are likely to be exclusively used for this purpose. Most designs are variations on just a few basic themes, and it remains to be seen which will continue to be created and used in the coming decades. While some good research towards workable systems has been done in the last few years, some designs still being produced show little sign that their perpetrators have kept up with recent developments.

Larger projects especially are often put together by the committee approach, where several consulting organisations are asked to collaborate. Each of these organisations will usually have a well-earned reputation in other fields, although that doesn't mean that they will be able to produce a coherent wetland design. An engineering firm will be called upon to produce the overall design, a landscaper will be in charge of aesthetics, a botanist will be asked to produce a list of plants known to occur in the area, and a nursery will be required to propagate and plant an apparently randomly chosen assortment of these.

There are many weaknesses with such a system and the results produced can be unfortunate; I have seen wetlands that needed irrigation systems to keep the inappropriately chosen plants alive at times! In another case, a channel planned and planted to improve water quality downstream, created an erosion problem and increased sediment loads instead. Such examples are not all that rare, and this problem is not confined to Australia alone. It is not all that long since a well-funded program in the UK created wetlands at a 4-degree angle to increase the rate of flow. The water certainly flowed through quickly, and not enough remained to keep wetland plants alive.

Many water treatment wetlands are also too small for the catchment area or run-off volume they are expected to service. It should be obvious that a one-hectare wetland will have little effect on the quality of water running off 100 hectares. Unless the wetland area is large compared to the catchment area being serviced, it may be necessary to recycle water by pumping, to increase the time available for treatment. On a sloping site, a series of smaller, narrow channels flowing from one into the next downhill can act like a larger wetland, and the channels will reduce the need for baffles to maintain uniform flow.

The most basic type of treatment wetland is filled by surface flows, where water runs through a shallow basin that is heavily planted. The rate of flow should be kept as uniform as possible through all areas, and various combinations of baffles and channels may be used for this purpose. Such wetlands must be precisely levelled, and in large-scale work laser grading is used for accuracy. On a smaller scale, the area to be used should be flooded shallowly once it has already been roughly levelled. The water surface can then be used as a benchmark for levelling with a hand-held hoe, and this is probably how even large flat areas such as the bases of the Egyptian pyramids were made.

Some wetlands use an open substrate for plant growth, with water flowing beneath the surface only. Useful in areas where mosquitoes are a problem, this method leaves no open water for them to breed in, though there are many other options for mosquito control including introduction of fish or carnivorous insects such as backswimmers. The ultimate extension of sub-surface flow wetlands is to simply use the water to irrigate terrestrial plants, particularly tree plantations. This is a favoured method for disposing of water which has such serious quality problems that it should not be allowed to return into natural waters.

Some promising systems allow water to flow downwards through a loose substrate such as sand, densely packed with the living roots of various reeds and rushes. These vertical-flow wetlands have mostly been used for small-scale water treatment to date, as it is difficult to keep the downward water movement uniform over larger areas. As the root zone retains reasonable oxygen levels with this type of flow, wastes are broken down more rapidly than in oxygen-poor environments.

None of these designs will cure serious water quality problems such as heavy detritus loads, industrial contaminants, or excessive manure and organic waste levels, so pre-treatment to filter or sediment out unwanted materials may be necessary. Yet no matter how good the pre-treatment, sediments and nutrients build up gradually in every wetland, as well as organic material from the plants themselves. All water treatment wetlands have a limited working life, and are likely to need at least partial scouring and replanting every few decades, depending on how quickly silt and decay materials build up.

Finally, it should be noted that effective water treatment wetlands offer a fairly restricted kind of habitat – they are shallow, show little variation in flow rates, and are often densely packed with a limited range of plants. Certainly, some animals specialised for life in dense reed beds such as bitterns, rails and a few insect larvae may thrive here, but species diversity is never as high as in more varied wetland systems.

3

Construction and layout

Laying out and constructing wetlands is not particularly difficult, assuming that you have access to the right types of machinery, skilled and sympathetic operators, and suitable soils or soil-substitutes. Unless the job is straightforward and the soil is a suitably heavy clay, you should make yourself familiar with the methods used to build water-retaining walls in difficult conditions, so that you can personally supervise the more critical stages – particularly compaction.

There are earthmoving operators who have their own theories on how best to finish a dam or wetland, and will take every shortcut possible – even when being paid by the hour, because they only believe in the methods they have always used. This is why one in three Australian farm dams leaks; the figure would probably be higher except that some soils will hold water no matter what you do to them! A further problem is that bulldozers are commonly used in dam construction, and do not compact all soil types adequately.

When you initially look for potential dam sites, aim to find places where a minimum of earthmoving will create a maximal area of wetland – for example, by blocking narrow gullies with extensive, undulating areas behind. However, suitable water retaining soils are also important, and should ideally be under the intended site or reasonably close to it, as shifting earth and clay around unnecessarily is expensive.

A ground survey with just a surveyor's level may be all you need to set out future wetland boundaries, and most earthmoving contractors will have one of these available. However, for very large areas it is sometimes useful to be able to work from an aerial photo initially. These may be available from government authorities, but private pilots sometimes photograph a whole district and then advertise availability of their photos in the areas they have covered. Mapping software can lay in contours as small-scale as a centimetre over such photos, and contoured photos may help you avoid making mistakes such as drowning trees and shrubs that turn out to be unexpectedly near areas to be submerged.

Soils and construction

Commonsense will solve most problems that come up during excavation into a watertable, but construction of a water-retaining wall requires the specialised methods of dam construction. The first step is to check whether the clays available are suitable, or will need special treatment. Moist clay which can be rolled to a pencil thickness, and then bent into a U-shape without breaking apart, will hold water once it has been compacted. Dispersive (poorly structured) clays break much more easily, because their particles do not stick together properly when wet (see Colour Plate 5b).

There are varying degrees of bonding in dispersive clays; weakly dispersive clays may make a satisfactory wall without much special treatment, while for others it is best to obtain specialist advice. Strongly dispersive clays dissolve readily in water, forming electrically charged particles that can only be settled by changing the electrical conductivity of the water. This is usually done by the addition of electrolytes such as lime (particularly in the form of gypsum), or by otherwise increasing hardness or salinity of the water.

Waters containing highly dispersive clays should clear at around a total hardness of 250–300 parts per million, so curing a muddy water problem of this kind will also indirectly fix the water-holding ability of the wall. This is why clear dams do not leak appreciably if they have also been properly compacted. It is usually only *disturbed* dispersive clay soils that will seep, or in the case of walls – the water may even tunnel through with time. The same material left undisturbed below the original soil level generally holds water perfectly well. Untreated dispersive clays can be used to make up the bulk of a water-retaining wall, as long as there is a layer of good quality water-retaining material either lining the inside of the dam or as a core inside the wall.

Once the nature of the clays available is known and allowed for, the next step is to work out how much material is available, and where. A rough estimate can be made with a hand-held 10 cm diameter earth auger, taking samples in a few places over the planned site. These augers are only about 90 cm long, but can be extended another couple of metres with additional sections of steel pipe if you need to auger deeper for suitable material.

The first step in construction is removing all topsoil from the site, and stockpiling it nearby until the water-retaining structure of the wetland is finished. Layers of the topsoil can then be spread back over the wetland, mixing in any additional materials at the same time (fertilisers, organic matter) as required –

even a bulldozer can do this quite efficiently. It is often recommended that the topsoil be replaced uniformly over the whole area of a wetland or dam, but it is wasted in deeper waters as few water plants will grow much below a metre except in the clearest waters. Unless you have plenty of topsoil to spare, save it for the shallows (see Colour Plate 7a).

Construction with abundant material

The whole retaining wall can be made of suitable water-retaining material, if you have an abundance of it. Before the wall is built up, the subsoil from which it will be started must be scarred and loosened slightly to a depth of around 5 cm, allowing the base and wall to bond together more firmly. (If the wall is just built up from a smooth surface, water may seep through between the two faces, and in extreme cases the whole wall may slip along this line.) The tines on the back of a bulldozer are commonly used for this scarring procedure, after which wall materials can be packed into place layer by layer.

There is no such thing as a *completely* water-tight earth wall; even well compacted, high quality clays seep, however slowly. The greater the pressure the clays are under, the greater this seepage will be, and the more care must be taken to keep this to an acceptable level. Pressure is directly related to water depth, not to the total amount of water held in a dam or wetland. A retaining wall with water 10 cm deep behind has one-tenth the pressure at its base, as the base of a wall with a metre of water pressing on it. A wall holding back 1 metre depth of water has the same pressure on it whether the wetland is 100 square metres or 100 000 square metres in area. For this reason it is not usually as critical to achieve maximum compaction on a retaining wall for a shallow wetland, as it is for a deep dam. However, if the area of the wetland is large, the wall will probably need protection from wave erosion even though there is not much actual pressure behind it.

Once the wall is fully built up or close to it, the inside and any other uncompacted areas which have been stirred up during building must be compacted to reduce seepage to a minimum. For walls holding back 3 metres of water or less, a single rolled layer (six or more passes of a roller) should be enough. For deeper waters, each further 3 metres of depth requires a further loose layer of material around 30 cm deep. This should be spread over the previously rolled surface, and be rolled separately. Thus, in a dam 9 metres deep, there should be at least three separately rolled layers in the deepest parts. Two layers would be adequate in those areas that are less than 6 metres deep, and one layer for 3 metres of depth.

Construction with limited material

If there is not enough suitable material to make up the whole retaining wall, what there is should be saved to make a skin or a core, and the bulk of the wall must be built up of whatever other soil is available. If there is a good layer of water-retaining material *underlying the whole area* of the dam or wetland, a core of the same material running down through the centre of the wall will keep water in. This must be dovetailed into the underlying layer, by putting in a trench at least 30 cm deep from which the core will be built up. The taller the wall, the deeper and wider this trench should be.

The core is just a column of water-retaining material built upwards from the trench, with sloped supporting walls on either side which are made up from whatever other soils are available; these are built up at the same time as the core. Unless the core is made from high-quality material that doesn't need compacting to give a water-tight seal, it should be built up in layers of about 30–40 cm depth, each of which is rolled before the next layer is spread on top.

If there is no suitable layer of water-retaining material under the site, the basic shape of the entire wetland or dam can be carved out of whatever soils are available. It can then be lined with a skin (or blanket) of material that does retain water. This skin should be thickest in the deepest areas, up to 60 cm in water 3 metres deep. It can taper to as little as 30 cm in the shallows where there is little pressure, if there is likely to be no problem with tunnelling freshwater crayfish. The skin should be rolled, with an additional rolled layer 30–40 cm deep being laid on for every additional 3 metres of depth.

Alternative materials

Not all sites have good water-retaining material available. Some soils can be modified to hold water, for example by the addition of lime, sodium tripolysulphate, or other chemicals which will improve their structure. These alterations require expert advice on type, dosage and application of each chemical, although you can guess the amount of lime to add to dispersive clays, if you don't mind the extra cost if you overdo the amount. Random amounts of other additives won't do any good, and may even prevent the soil from ever being capable of holding water.

Water-retaining materials can also be brought in from elsewhere to line a dam or wetland. Usually, the simplest and least expensive of these is good quality clay, applied to form a skin as already described (see Figure 3.1). There are few properties where suitable clays can't be found somewhere nearby.

Various types of synthetic liners are available for dams, varying considerably in cost, strength and expected life span. Tough, long-lasting liners such as EPDM membranes can be joined to cover any area, but are very expensive. Butylene liners are comparable in quality but are even more expensive, and in my experience are prone to come unstuck along their welded seams. Liners must be covered with soil to give a natural bottom; this is generally done by machine, and cheaper liners will be fairly easily damaged during this stage.

Bentonite clays are another expensive solution, although they can be applied quite thinly in shallower areas. These are usually bought as a dry powder that

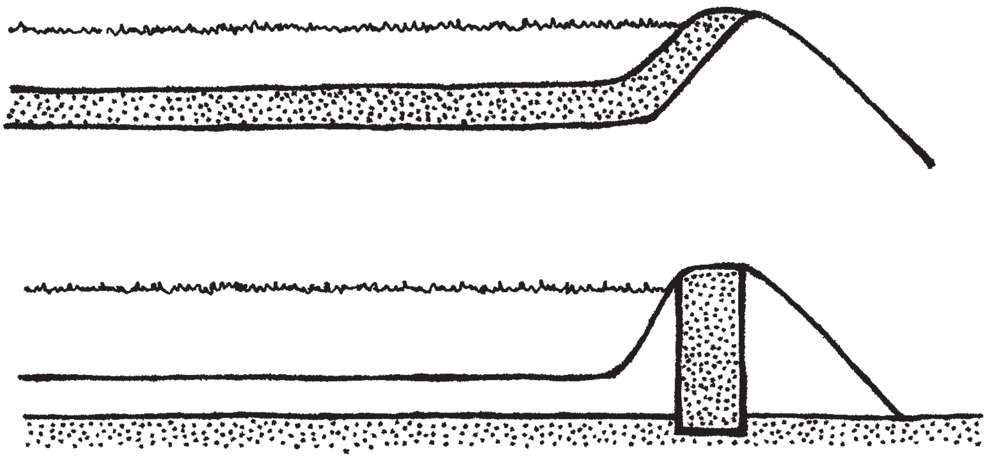


Figure 3.1 Sealing the water-retaining wall on sites with limited good quality material. Above, a clay blanket lining the entire wetland, below a clay core dovetailed into the underlying clay layer.

expands dramatically when wetted, increasing from about 10 times in volume for calcium bentonite, to as much as 17 times for some types of sodium bentonite. Bentonite is laid as a dry blanket under a layer of topsoil, swelling when wetted to form a layer impervious to water.

Still more expensive but easier to use are bentonite liners, basically a woven, three-dimensional matrix mat packed with dry bentonite, and unrolled onto the area to be lined using a special arm on an excavator. The individual rolls are overlapped by about a metre, and covered with a blanket of soil to protect against weather. As the dam or wetland fills, the bentonite expands and the mat becomes almost impregnable – so these liners are even used to keep toxic liquids from seeping into ground water.

Straw, leaves and manures are also sometimes used to try to seal sandy soils with a layer of well-rotted organic matter called gley, an effect similar to the peaty bottoms of lakes that form among sand dunes. This method is rarely used in Australia except where such materials are available locally in considerable amounts, and are inexpensive, but a similar effect for a shallow wetland can sometimes be achieved through fencing a substantial flock of sheep in the area to be sealed. These are fed straw or hay, and over a period of time their manure and trampling hooves create a shallow, waterproof layer – the original sheepsfoot roller.

Machinery

Deciding on the appropriate machinery to use for earthmoving is usually simple once the wetland has been laid out, and the materials available are known. Combinations of machines will be most effective in many cases, for example a small bulldozer and an excavator have maximum manoeuvrability for shaping a small wetland (see Colour Plate 7b). A large bulldozer and a scraper are more appropriate for creating a large wetland, the bulldozer speeding the scraper's work by loosening soil and pushing this into its path.

Excavators and backhoes

These are digging machines with a long arm finishing in a bucket for lifting soil. Backhoes are the smaller machine, and are only useful in very small areas because both their reach and bucket size is limited. However, they can do some reasonably fine detail work, and shift rocks and logs around during landscaping (really precise trimming can only be done with hand tools, although this isn't practical over large areas).

Excavators are more powerful, with a much longer reach and a much larger bucket; they are also mounted on caterpillar tread that allows them to work in places where a backhoe can't go. They are particularly useful for digging below a watertable, and for contouring shorelines. They can also be used for detailed work in wetlands constructed by bulldozers or scrapers, neither of which can create fine channels, or for making smaller ledges and planting pockets.

Never excavate directly into wet areas over which water flows for even a part of the year, as this can cause serious erosion problems. Deeper pools around such areas are best dug well to the side of the main flow, where they will be filled by overflow.

Bulldozers

These are most useful for general earthmoving, and come in a wide range of sizes suited to many different jobs. Smaller bulldozers are good for landscaping in skilled hands, while larger ones are more efficient at moving earth in terms of cost per volume shifted. The caterpillar tread they run on is designed to spread their weight, not for compaction, so they should be used in conjunction with a sheepsfoot roller or the walls they build up will often leak.

Scrapers

Basically a specialised truck, the scraper's 'belly' is a gouge that can be lowered to scrape up soil or clay, for shifting it to another area where the contents will be spread. Scrapers work most efficiently over larger areas where they can follow a continuous loop, picking up soil in one area and dropping it in another, and circling back to pick up another load without slowing down unnecessarily (see Colour Plate 8a). They are fairly heavy themselves, and a big scraper of 30 or more tonnes can carry close to 50 tonnes of soil as well (all this weight concentrated in the small contact area of tyre and ground), so they give very good compaction as they pass over the same areas repeatedly.

Rollers and compactors

On sites where only a bulldozer is used, compaction is usually poor unless a roller is also used. Soils with as little as 20% of a suitable water-retaining clay can hold water if they are well compacted with a sheepsfoot (also called a calfsfoot) roller, while the soil is reasonably moist. These are heavy cylinders running on many spiky feet, and are passed over the same area six or more times for best results. In the early passes, their feet sink in to the hilt. By the last pass, the roller should be tiptoeing around on the ends of its feet, and the ground may be so hard that a shovel will ring if struck on the finished surface.

Over smaller areas, a four-wheel drive tractor can be used to pull a detachable roller. Although a bulldozer can easily pull a smaller roller like this, it is uneconomical to couple and uncouple frequently, and bulldozer time is more expensive than tractor time. Over larger areas, a self-propelled sheepsfoot roller should be used; these usually also have a blade for fine trimming, and vibrate so that compaction is done more efficiently.

Other combinations of machinery and roller can also be useful – for example an excavator can be used to tow a roller over steep slopes or slick surfaces where other machinery is in danger of sliding in (see Colour Plate 8b). The rough surface left after this type of work can then be smoothed with a vibrating plate, also attached to the excavator's arm.

Laser grading

On sites where precise control over flow rates and directions is necessary, especially in larger water treatment wetlands, lasers are used to determine exact gradients. This technology is already widely used by most of the larger earthmoving businesses, as it speeds up the layout and planning of a wetland area considerably.

Water control

All wetlands and dams that have water running through them at any stage must include ways of controlling water going in or out of the system. The most basic of these is an adequate overflow or by-wash, that allows water to escape during wetter periods, or the retaining walls may be breached by water pouring over them. Where the total catchment area draining through a wetland is small, an overflow can be as simple as a concrete pipe or two passing through the wall, and this also allows light traffic to use the wall above. Where the catchment is large, the overflow must be broad enough to carry floodwaters so that these do not bank up too much.

Overflows are usually situated to the side of a retaining wall, so that the escaping waters can be directed away from the wall itself to prevent undercutting.

The overflowing waters should be directed along a ramp sloped as gently as possible on that site, and held together by dense plantings of appropriate plants, heavy gravel, or even concrete if the slope is steep. Overflows that can be opened and closed as necessary have the potential to help reduce flooding downstream in periods of heavy rain, by keeping back some of the water to be released later when the main flood has already passed.

Even at drier times the ability to control the drainage of water from a wetland can be useful, especially to empty it if required – this is called drawdown. Although little used in Australia at present, drawdown is likely to become an increasingly useful management tool, especially in the control of weeds and vermin. In constructed wetlands and dams, there are two parts to an effective drawdown system; a sloping floor or sloping drains leading to an internal sump, and a way of removing the water when necessary.

Sloping floors limit how a relatively shallow wetland can be designed, because they create a regimented arrangement of slopes that may not fit well with other plans. A simpler variation is drainage lines across the floor of a wetland. These should slope slightly downwards as they run into deeper channels, all of them ultimately leading to a sump. If the wetland is drained, this sump will be the last remaining pool of any size on the floor, so it will be easy to rescue native fishes using a net, and to lime heavily to kill any unwanted exotics that remain.

Water can also be pumped out, siphoned out, or allowed to drain along a permanently fixed pipe passing through a retaining wall (if there is one). Siphon lines may be relatively slow to drain a large volume, but have two advantages – they are less expensive than installing permanent pipes, and do not potentially weaken retaining walls. However, they can only be used where the bottom of the wetland is not too far from an even lower point that water can be siphoned down to. Where a series of smaller wetlands is planned, one siphon may be all that is needed, as it can be shifted around as required.

A simple siphon can be made from a piece of agricultural polypipe – the larger the diameter this is, the faster the flow rate will be as friction becomes proportionately less for the volume of water moving through. The siphon is weighted at the siphon (sucking) end and has a valve to control flow at the other end. The pipe can be filled from below with a pump, or can be pushed underwater section by section by hand, to fill it gradually, in which case a sealable valve at either end will make it easier to manoeuvre the filled pipe around without accidentally getting air into the line. The valves are shut once the whole line is filled, and one end is then pulled over the retaining wall to a level below the lowest part of the wetland. The *submerged* valve is opened first, *then* the valve below the wall.

Pipes can be built through retaining walls, but as they are a potentially weak point considerable care must be taken. The pipe itself must have watertight baffles welded, glued, or otherwise firmly clamped at regular intervals along its length. Water will tend to flow along the surface of smooth pipes, eroding a tunnel, and the baffles block any water movement along the pipe. This type of tunnelling effect sometimes breaches dam walls – water will even travel along a piece of fencing wire, if it runs right through the wall, eventually eroding an unblockable pipeline.

Pipes through walls are usually set in a trench that runs below the base of the retaining wall. As this area will have more water pressure on it than any other part of the wall, the soil around the pipe must be compacted in thoroughly. On a small scale, this job must be done by hand, and a dirty, tiring job it is too! On wider walls, compacting wheels designed to fit onto the arm of an excavator can be used instead.

The underwater landscape

The arrangement and type of soils below the surface decide where, how and which plants will grow, in turn deciding the very nature of a wetland as these are a dominant part of many habitats. Suitable soils and growing conditions for plants are discussed in Chapter 5; however, the base over which the soils are to be spread is a part of the framework of the dam or wetland.

In a natural wetland, underwater slopes often descend fairly quickly into deeper waters, but it is not a good idea to try to imitate this in a newly constructed wetland. Loose soils on a sloping base will tend to slip or wash into deeper parts of the dam or wetland. To counteract this tendency to slippage, constructed planting areas should be level, or even slope slightly away from the deeper areas. With time, the shoreward side of each level area will tend to build up with new material washed in, or eroded by wave action, to give a more natural profile, and plants will have plenty of time to adjust themselves to such changes.

Planting areas can be loosely divided into shelves, plateaus and pockets. Shelves are often much the same width over their whole length (although they do not have to be), while plateaus can be almost any shape. Pockets are smaller, often dug in by hand, and are usually used as a way to separate plants, contain patches of more spreading species, or to provide a tailored soil mix for a plant (such as a waterlily) with specialised needs. The depth of any shelf, plateau or pocket should be chosen to suit the plants you wish to grow in that area, so you should have a good idea of the species you intend to use before construction has even begun.

There is no reason to keep shelves, plateaus and pockets always separate and clearly defined; a wetland is not a formal flower garden. However, for a more natural appearance the underwater landscape should be arranged to give some impression of zoning (see Figure 3.2). For example a shelf running along an edge and planted with no more than two or three species can be made to look much like the edges of many billabongs or other natural wetlands. A deeper shelf a bit further out with deeper growing species will help to extend the illusion. By contrast,

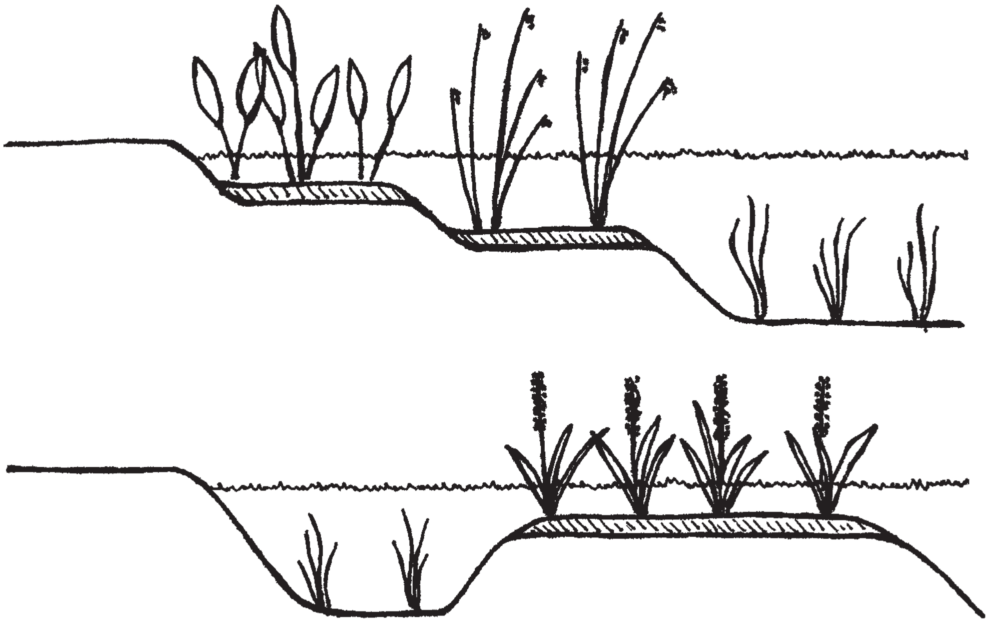


Figure 3.2 Planting shelves above, covered with a layer of soil, and a plateau below.

plateaus of a fairly uniform depth will allow extensive stands of various sedges to develop, rather than narrow zones.

When planning areas like these, the depth of the base should allow for the addition of a layer of soil on top. The final depth of a planting area is not measured from the underlying clay, but from the surface of any soils spread over it. For example, a shelf base 15 cm deep with 5 cm of soil over it will give a planting area 10 cm deep. Deeper blankets of soil are better if enough is available as they will hold moisture longer than the compacted clays which often underlie them, but there is rarely any need for soil depths greater than about 15 cm. Shallower soils will dry out sooner once water levels have fallen below their shelf or plateau, so these are best planted with more drought-tolerant species.

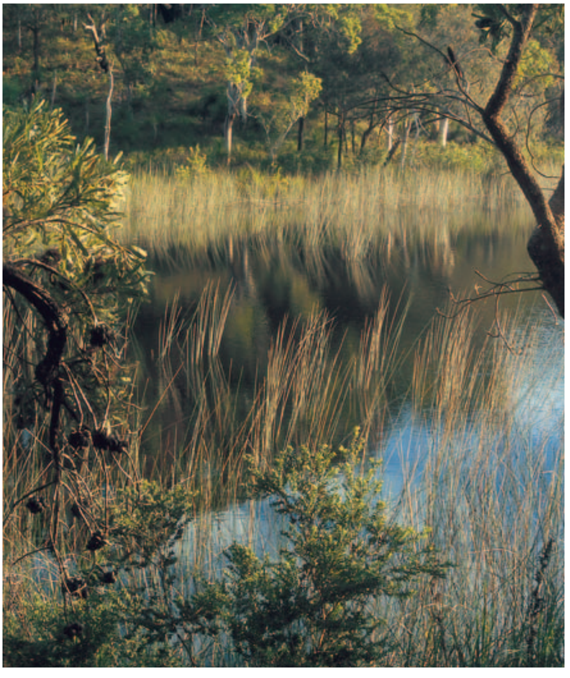
a) Swamp banksia (*Banksia robur*) growing among *Melaleuca quinquenervia* in southern Queensland. The banksia will only tolerate flooding for days at a time, while the deeper-rooted paperbark suggests the underlying watertable is close to the surface at least during the wetter months.

b) The drought-tolerant canegrass (*Eragrostis australasica*) growing in a Western Australian claypan that may only fill with rain every few years.

a) Black swamp on Kangaroo Island in South Australia, the water tinted black by tannins that limit the diversity of plants which can grow here.

b) Giant rush (*Juncus ingens*) growing on the banks of the Murray River, part of Australia's largest internal drainage system with its own distinctive flora and fauna.

a) A billabong near the Adelaide River in Northern Territory, with the indigenous waterlily *Nymphaea violacea*. Filled by floods during the wet season, the billabong will dry out and its plants will apparently disappear as the hot season progresses.



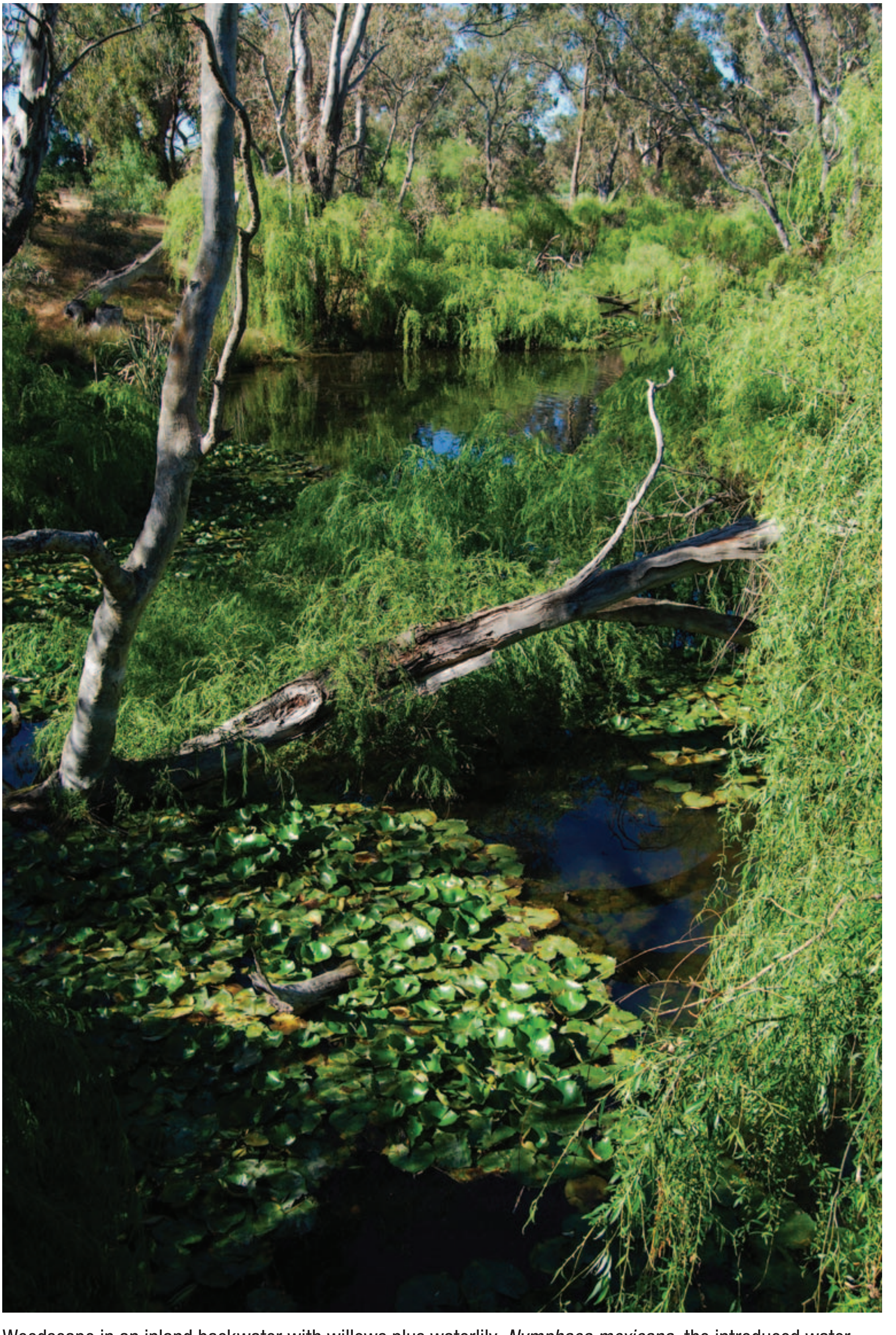
b) Blue lake on Stradbroke Island in Queensland, with the tall sedge *Lepironia articulata* thriving despite occasional battering by waves during storms.

a) Zones in a saltmarsh in central New South Wales with the red succulent *Sarcocornia quinqueflora* replaced by the creeping grass *Sporobolus virginicus* on higher ground, with a band of the greyish *Juncus kraussii* and then mangroves as the land slopes down to the sea behind.

b) Ball's dam in south-western Victoria. The tree planting was done in an attempt to reduce salinity in waters flowing into the catchment downstream, but will also ultimately reduce flight paths into the wetland for the diverse range of visiting waterbirds.

a) An 'ornamental' lake in the inland, created under the assumption that water could always be pumped from river systems that have long been under stress from overuse of their waters.

b) A failed dam in Western Australia, built with uncompacted dispersive clay that only holds water to the undisturbed level below. The pine tree growing at the highest possible water-holding level indicates how rarely the water rises to this point.



Weedscape in an inland backwater with willows plus waterlily, *Nymphaea mexicana*, the introduced water milfoil *Myriophyllum aquaticum* and the surrounding land a mass of pasture grasses and prickly weeds.

a) Newly constructed dam with topsoil replaced only on the highest levels.

b) An excavator, and a bulldozer with a sheepsfoot roller.

a) Scraper constructing a shallow wetland.

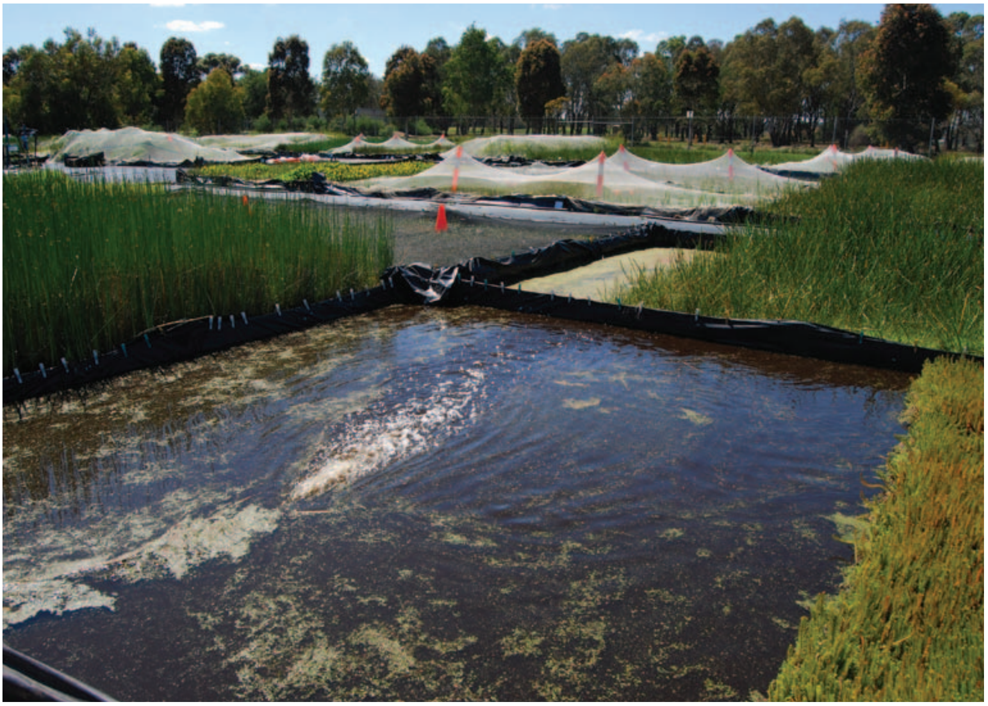
b) A sheepsfoot roller with a self-contained vibrating motor, manoeuvred by an excavator over a slick clay wall where other machinery could not safely operate.

a) *Baumea articulata*, a good water treatment plant that is not as invasive as some other larger sedges and their relatives.

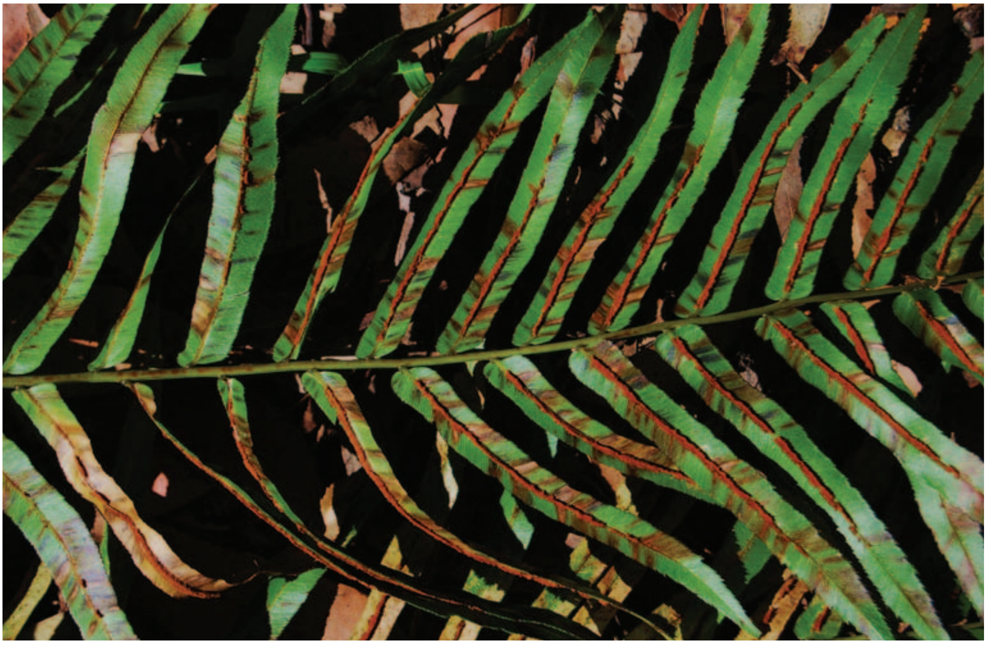
b) River clubrush seeds in a duck feather.

a) *Cotula coronopifolia* is often among the most ecologically important plants in slightly saline wetlands, here at the eastern end of Kangaroo Island, SA.

b) Floating trays, a simple way to propagate water's edge plants.



a) Part of the propagating areas of a large wetland nursery.



b) Bungwahl (*Blechnum indicum*) is one of the most aquatic of the waterferns, and unlike most others produces its strings of brown spores along the midribs of fertile fronds, which otherwise look barely different to the non-fertile ones.

a) Water snails can destroy soft-tissued plants if allowed to build up.

b) A diverse shoreline community with *Azolla pinnata*, *Ricciocarpus natans*, *Potamogeton sulcatus* and *Triglochin multifructa* growing at the fringes of an artificial wetland.

a) *Myriophyllum simulans* and *Eleocharis sphacelata*. Both of these indigenous species can form extensive stands where little else will grow, possibly through the use of allelopathic chemicals.

b) Planting bare-rooted wetland plants.

a) Bird netting used to protect a recent planting in an urban setting with excessive numbers of ducks and coots.

b) Prop roots of *Rhizophora stylosa*, a mangrove.

a) *Alisma plantago-aquatica* against redgum reflections.

b) *Bolboschoenus fluviatilis*.

a) *Calystegia sepia*.

b) *Carex fascicularis*.

a) *Crinum pedunculatum*.

b) *Cyperus exaltatus*.

a) *Samolus repens* growing with the grass *Distichlis distichophylla* in a saline ditch.

b) A dense stand of *Eleocharis dulcis* with two tropical paperbarks (*Melaleuca viridiflora* at centre, and *M. cajuputi*).

a) *Eriocaulon setaceum*.

b) *Eryngium vesiculosum*.

a) *Fuirena umbellata*.

b) *Gahnia clarkei*.

a) *Gleichenia* and *Sticherus* are closely related, but the brighter-green *Sticherus* has less finely divided leaves.

b) *Glossostigma elatinoides*.

a) *Isolepis inundata*.

b) *Lepidosperma longitudinale* flowering in a dry lagoon.

a) *Malva preissiana*.

b) *Mazus pumilio*.

a) *Meeboldina scariosa*.

b) *Monochoria cyanea*.

a) *Myriophyllum salsugineum* growing submerged in deep, clear waters.

b) *Nymphaea pubescens*, an indigenous night-flowering waterlily that closes up soon after daylight.

a) *Nymphoides minima*.

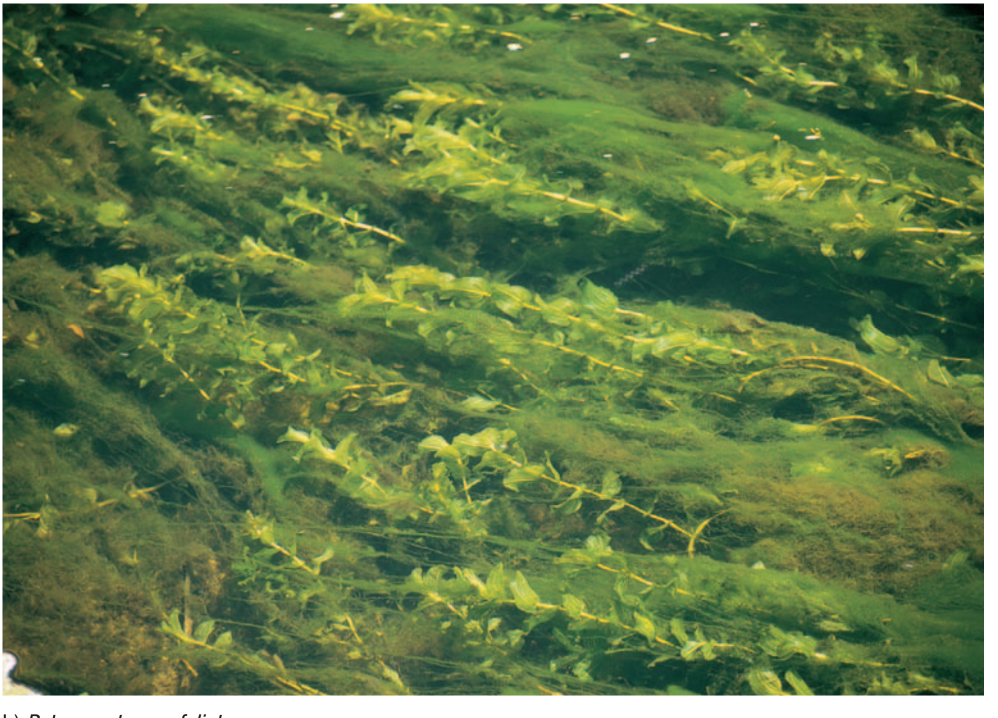
b) *Oryza rufipogon*.

a) Oval leaves and three-petalled flowers of *Ottelia ovalifolia*, with occasional plants of the waterlily-like *Nymphoides indica*.

b) *Pandanus aquaticus*.

Persicaria decipiens.

a) *Philydrum lanuginosum*.



b) *Potamogeton perfoliatus*.

a) *Rhynchospora corymbosa*.

b) *Ruppia polycarpa*.

a) *Schoenoplectus pungens*.

b) *Selliera radicans*.

a) *Todea barbara*.

b) *Triglochin procera*.

4

Provenance and plant selection

Before considering the many ways in which wetland plants can be propagated (described more fully in the next chapter), we need to have a good idea of what species are appropriate for any planting, and where it is appropriate to collect propagating material from. This chapter looks at these and related issues ranging from the apparently worldwide distribution of some closely related wetland plants, to how close to home they should be collected, and selecting plants for various purposes and conditions.

Provenance and wetland plants

The most basic rule-of-thumb used for selection of propagating materials in revegetation is to propagate from plants or seed obtained from as close to the planting site as possible. These are regarded as being of 'local provenance', and the underlying assumption is that they are better adapted to their local environment than plants from other sources further away.

While this is probably true for many groups of terrestrial plants, the logic doesn't always hold up to close scrutiny for at least some wetland species. Restricting the allowable sources of propagating material may reduce these to a single wild stand for some species in some areas, and where a plant has disappeared as a result of drainage or other changes, there are those who would not consider 'reintroducing' it from a little further away even if it is also endangered elsewhere.

In the case of some wetland plants such as sedges, isolated stands may be genetically identical; that is, a single, large clone. It is not improbable that a single, long-lived, running clone of this kind (and we have no idea how long a single sedge is likely to live) may eventually spread to occupy an area of many hectares. Self-sterile clones of considerable size could explain some difficulties in obtaining viable seed, from what superficially look like populations but are just one individual.

For example, a stand of around 12 hectares of jointed twigrush (*Baumea articulata*) I have visited regularly for around two decades has never managed to get seed to maturity (see Colour Plate 9a). In cultivation, the same plant sets moderate quantities of viable seed if it flowers at the same time as others of its species, from other locations. The very abundant and widespread cumbungis (*Typha*) are also commonly found as single-clone populations. Their flowerheads may vary considerably in appearance between particular wetlands and dams in the same general area, yet those on individual clumps are often identical in appearance, suggesting that even large stands are often from a single seed. In many localities and dams I have observed over the past three decades, this has definitely been the case.

If genetic variability is to be retained or restored in revegetation work, it is therefore desirable to bring in planting materials from a number of sources, rather than just one. This raises the question – how far away is acceptable, what is the furthest distance revegetating sources can be? In the USA, where considerably more work has been done on revegetation biology and for much longer than in Australia, 80 km is generally accepted as local enough for source materials for planting, though even this figure is regarded as too restrictive by many. Yet it is just a guess and not some scientifically validated figure, as is immediately obvious when it is converted into the distance units used in that country: 50 miles.

Guesstimates of an appropriate collecting radius are usually based around wider experience with terrestrial species, but these are mostly able to spread overland by seed or by runner. A population front spreading overland in the form of seedlings will tend to select for those plants best adapted to the new areas being colonised, with further adaptation to follow through local selection over many generations.

This doesn't happen in the same way with most aquatic and wetland plants, because of the fragmented and sometimes short-lived nature of their habitats. Even the largest wetland will disappear with time, and successful wetland plants must be able to get their offspring to new wetlands before their time is up – sometimes over great distances, as will be discussed later. Conditions within each wetland also change with time and siltation, some plants dying out when others better suited to the changing conditions move in.

The ability to 'jump' from one site to another must therefore be a primary adaptation for many, if not most wetland plants, as almost none of them have any chance of survival on drier land, however temporarily. For some, the adaptations are obvious. For example, the two native cumbungis are found across much of Australia because their tiny but copiously produced seeds are attached to fluffy filaments that the wind can carry great distances.

Close inspection of the seeds of many other wetland plants will show various hooks, bristles and projections designed to catch onto feathers or fur, though mammals are not as wide-ranging as birds so they are less desirable vectors. Some of these seeds are almost impossible to dislodge once they are wedged, especially in down feathers, and the viability of such seeds is usually many years while waterbirds moult their feathers at least once a year. Between moults, some waterbirds (especially swans and ducks) travel thousands of kilometres, following rainfall in the hunt for feeding and breeding grounds anywhere on this continent, or even overseas.

Waterbirds prefer a well-watered place for their moult, so feathers carrying seeds are likely to be shed in some kind of wetland where they will float until they come to lodge at the water's edge (see Colour Plate 9b). These are ideal conditions for germination: a dry dormant period, followed by soaking and then stranding on waterlogged soil. A further advantage to winged travel for these seeds is that the feather is nitrogen-rich and will decay to release a variety of nutrients around the growing seedling. This gives the young plant a significant boost, as planting identical seeds onto a sterile soil mix, one with and one without a feather, will show.

It is not surprising that many aquatic plants with seeds that lodge in feathers are found over much greater ranges than most terrestrial species, even though they are spread much more patchily. For example, tall spike rush (*Eleocharis sphacelata*) crops up frequently even on the bare, compacted clay of new dams in Australia, New Guinea and New Zealand. Plants from extremes of its range show little difference in appearance, or growth and climatic responses – also not surprising when you consider that the parent plant of the spike rush in the dam just up the road could be thousands of kilometres away.

It would make little sense in evolutionary terms for such a widespread plant to develop significant adaptations to purely localised conditions, because its primary adaptations must be to spread by migratory birds. Once it gets to a new home, a secondary but equally important set of adaptations comes into play: tall spike rush will grow anywhere from the tropics to southern Tasmania. This is the *opposite* of local adaptation, and for such far-travelling plants, the concept of 'locally' sourced propagating materials does not mean a thing.

Tall spike rush is not exceptional among aquatics, and in terms of far-flung natural distributions is somewhere around the middle of the range. There are many other widespread aquatics, some found through all of Australasia, others across all continents with the exception of Antarctica. These cosmopolitan wetland plants include *Brasenia schreberi*, *Cyperus polystachyos*, *Hydrilla verticillata*, *Isolepis fluitans*, *Phragmites australis*, *Potamogeton crispus*, *Stuckenia pectinata* and *Schoenoplectus pungens*.

Others are more restricted (if that is the right word) to just Asia, the Pacific islands and Australasia, including *Baumea articulata* and *B. juncea*, *Philydrum* *lanuginosum*, *Potamogeton ochreatus*, *Schoenoplectus tabernaemontani*, *Typha orientalis* and *Lepironia articulata*. The latter is also indigenous in Madagascar though it was probably carried there by humans in their migration from Indonesia across the Indian Ocean, in the form of seed attached to sails woven from its fibre.

Many comparable examples could be added to these brief lists, even without touching on wetland ferns that spread by tiny, windborne spores, or the plants of coastal wetlands. There are also numerous wetland species that are 'merely' widespread over a range of climates within Australia alone.

At least a few of these cosmopolitan plants will prove to be two or more species when they are studied more closely. In my own experiments with imported seed in the early 1990s it was interesting to see how different the resulting plants were from Australian populations in many ways, from the treatment they needed to germinate to what triggers ended their dormant periods – and even how different the plants themselves sometimes looked, given that they were supposed to be a single species! For the record, all of these experimental plants were destroyed before they had a chance to cross-pollinate with Australian relatives.

These cosmopolitan species-groups have adapted genetically to different climates and conditions, yet they are very obviously still closely related. Even being so widespread that local adaptation genuinely becomes important, these species still require those primary adaptations most useful to any wetland plant – the ability to jump between wetlands that may be continents apart.

Not all wetland plants produce seed that can be carried by birds or by wind, and there are many lesser degrees of dispersive ability to be found. The less capable a plant is of jumping between wetlands, the slower genetic flow will be between its populations, and the more variation it is likely to show over a smaller range. Some of this variation will certainly be related to local adaptation, although genetic drift due to small founding populations is also likely to be involved. All such variation is worth preserving, regardless of how it has originated.

To summarise these disparate considerations, estimates as to how far away seed (and other propagating material) of wetland plants can be usefully collected should be based on the total range of any distinct form of any species, rather than applied as a single number to fit every case. Variation in genes (in the form of genetic drift) is likely to be greatest towards the extremes of any plant's range, so estimates should be centred around the area to be planted. I suggest that for most wetland plants, a spread of around 10% of total range (5% in any direction) would avoid unnecessarily bringing in genes that are not already present in the area.

This should also allow access to a reasonable number of more diverse gene pools for all but the rarest and most localised plants, which may often warrant a special exception in the interest of keeping them going. On the other extreme, for widespread species such as tall spike rush or jointed twigrush this allows an acceptable collecting distance of 200 km in any direction from the planting site. By contrast, dwarf water ribbon *Triglochin alcockiae* would need to be collected from within 50 km of any planned planting site, a distance in close agreement with observed variation between the distinctive populations of this species found in the Melbourne area, and in contrast to variation seen over the rest of its range.

Some readers will disagree with these estimates, but there are good reasons for adopting a more flexible approach than that of the past. Many populations of wetland plants have always been fairly isolated, and are even more so since European settlement because the distances between wetlands are on average much greater now. Those species with the most limited ability to disperse between wetlands have had their chances of passing genes on elsewhere reduced dramatically, and may even be trapped permanently in some cases, as global warming takes a further toll. The guidelines suggested should be an effective compromise retaining local adaptations, yet allowing the introduction of a little more diversity from not too far away.

Another biologically appropriate strategy for choosing sources of wetland plants for propagation is the catchment approach, where only propagating material from a single river system is collected. Where local adaptation has already begun, it will often be widespread within the same river system and its associated wetlands, and introduction of plants anywhere in the same area is unlikely to swamp recently evolved adaptations with unrelated genes from elsewhere.

This idea needs to be applied in a commonsense way. The Murray–Darling is by far too large a catchment system to count as one for localised adaptation, and even breaking it into the Murray and the Darling does little justice to the many different zones within these two rivers. On the other hand, restricting collection of material to a single small coastal river such as in the Otways where I live, and not allowing mixing with material from a similar stream a few kilometres away ignores the reality that all of these streams were but closely linked parts of the wider Barwon–Yarra catchment only a few thousand years ago.

Native or exotic?

For the past two centuries most aquatic plants found overseas as well as in Australia have been regarded as indigenous, unless there was reason to think they had arrived with European settlers. Over the past two decades a few of these species have suddenly become weeds in the eyes of a small but apparently influential group of botanists. Before we accept these as unwelcome introductions, rather than natives which have just had bad publicity, the putative reasons for the changes should be considered in more detail.

Waterbutton (*Cotula coronopifolia*) has long been regarded as native, but by the late 1990s was increasingly being listed in various Floras as an exotic (see Colour Plate 10a). I will use this species to show how dubious the unwelcome brand of exotic origin can sometimes be, and also present evidence from three overlooked papers that shows waterbutton was already widespread in south-eastern Australia thousands of years ago, and possibly elsewhere.

Waterbutton was a familiar plant around the Port Jackson settlement where it was first collected by Robert Brown, just after the turn of the nineteenth century. He had already seen the same species in southern Africa on the journey here, so included it on a list of 29 introduced and possibly introduced species for the Port Jackson area. Of these, waterbutton was one of the two species he tagged with a question mark, because its wide distribution around Port Jackson (presumably much wider than for plants which were obviously recent introductions) suggested it had long been established there.

As exploration of Australia continued over the next half century, waterbutton was found in wetlands both inland and along most of our southern coasts. If it *had* been a recent introduction at Port Jackson, it must have been one of the fastest spreading weeds on record, yet it has not been observed to spread into any new area since those times. In comparable areas of the Northern Hemisphere where it is definitely introduced, waterbutton has spread at a much slower rate, taking centuries to achieve its present and still expanding range. Waterbutton is also native to the southern parts of South America.

A distribution covering all Southern Hemisphere continents is not novel; for example, the sedge *Ficinia nodosa* (which no one doubts is native) has a similar range, although it is generally found on higher and drier land around coastal and some inland marshes, rather than in them. Other native saltmarsh species are more restricted in range, for example *Samolus repens* and *Selliera radicans* which are only found from Australia to South America, and *Juncus kraussii* which is abundant in both Australia and South Africa, though it is possibly a different subspecies there.

If waterbutton is native to all these continents, separated by oceanic distances, or even just South Africa and South America, how did it spread? As this species will tolerate salinities nearly twice that of seawater, and broken-off pieces I have floated in seawater have started putting out roots after four months, it isn't hard to see how living pieces of this plant could survive a sea journey. Stranger and much more delicate things have floated across the Indian Ocean, not least two sub-fossil *Aepyornis* eggs from Madagascar (the largest of all eggs known) which washed up undamaged in Western Australia. Broken-off pieces of waterbutton are far less delicate and vastly more common, as can be seen along some of our southern coasts after a south-westerly storm.

If waterbutton was in Australia before European settlement, its pollen should have shown up in some of the many sediment cores taken from lakes and swamps in south-eastern Australia over the past few decades – assuming that anyone was looking for it. Most pollen studies of this kind are looking primarily for terrestrial pollen to gain an understanding of the forests, grasslands and associated vegetation of pre-European Australia. These forests run for many kilometres in all directions, and the pollen of eucalypts, grasses and even some sedges is usually much more abundant than that of the aquatics which only form a thin band around the fringes of deeper lake waters.

Pollen records of aquatic species are incidental to studies of terrestrial pollen, and palaeobotanists generally don't bother putting much work into groups of incidental interest, because they don't tell you about the wider terrestrial communities being studied. This is why the daisy family (Asteraceae) to which waterbutton belongs is almost invariably just broken down into two subgroups, the Tubuliflorae and the Liguliflorae, with no effort made to separate these further into the hundreds of species potentially included.

However, three papers published decades ago by John Dodson (1979, 1986 and with Wilson in 1975) did differentiate *Cotula* pollen from the rest of the Asteraceae present. Now a professor of Earth and Geological Sciences in Western Australia, Dodson's 1983 study of modern pollen rain in New South Wales forms an important underpinning of the major synthesis of south-eastern Australian core samples by D'Costa and Kershaw (1997).

In many cases identification of fossil pollen to species level is difficult or even impossible, depending on the preservation of the granules, so Dodson's papers do not specify which of the three wetland *Cotula* found in lowland regions it comes from. These are waterbutton itself, plus the uncommon *C. vulgaris* (a native variant of a species also found in South Africa) and *C. australis* (also regarded without evidence as possibly introduced). A fourth native species from the high country (*C. alpina*) is found in moist, alpine herbfields or even *Sphagnum* moss beds, rather than near open water.

However, other records in the same papers provide an unambiguous comparison in the form of *Typha* pollen, as only one of these three candidates produces a similar volume of pollen to this prolific, wind-pollinated plant – and that is waterbutton. An informal comparison I carried out for the three showed that waterbutton produced on the order of a thousand times more pollen over its six month (and often longer) flowering season, than the other two did together. Furthermore, the others only flower on moist to wet soil, so nearly all of their pollen fell onto soil, and not onto the water's surface as was the case for waterbutton.

There are two interesting aspects to this conclusion, the first is that in two of the cited papers, *Cotula* pollen only goes back to around 5000 or 6000 years before the present (BP). In the third it appears around 10 000 years BP, but is missing from the 5000 years included before that. If this is not just a statistical fluke, it suggests that waterbutton has only been here for a few millennia. This may explain why it has not yet had the chance to develop the small differences local

C. vulgaris has from its South African cousin, which are the reason this less common plant has never been accused of being an introduced weed!

The other aspect is more disturbing. Despite published evidence that:

- waterbutton was widely distributed here even in the earliest days of European settlement;
- broken-off pieces can survive ocean crossings better than fragile giant eggs (seed carried by migratory birds is another possible means of spread which has not been discussed here);
- nowhere has it been confirmed as having been introduced by human agency;
- its pollen was present in deep lake core samples published 30 years ago,

it was first declared a weed in the third volume of the *Flora of New South Wales*, to be followed shortly after in the *Flora of Victoria*.

Waterbutton was not the only species relegated to this limbo. In Australia, this problem began with an article by Kloot (1984) ambiguously titled 'The introduced elements of the flora of southern Australia', where diverse plants with disjunct ranges (that is, with large jumps between their range in this country and overseas) are listed. Many aquatics are well adapted to long-distance dispersal between wetlands as has already been discussed, so a number of species in Australia that were previously regarded as indigenous, were *apparently* treated in this article as possible or even probable introductions.

Unfortunately, in most cases Kloot did not include anything resembling evidence as to which species on his hit-list were pre-European arrivals (and therefore native), and which were definite introductions. Every time I read this article it seems still more ambiguous and open-ended, even confusing. However, it seems to have had a profound effect on some botanists who have interpreted Kloot's paper in a proscriptive way. No one else disputes any longer that at least 30 of the wetland plants Kloot included, ranging from *Apium prostratum* to *Zannichellia palustris*, were here before Europeans arrived, but some of his readers have chosen to interpret most species he included as non-native until proven innocent.

On the other hand, some other species on this list which have fallen from grace could well be undesirable weeds. For example, the earliest records of *Sparganium erectum* from southern Australia are nearly all from a century and later after European settlement, and it has apparently been spread slowly by birds in the southern part of its range since – suggesting that it is introduced and its earlier native status may be in error. An increasing spate of Queensland records since 1964 also suggests weed status, that it flowers and sets seed more readily in warmer climates, and that it would be a good idea to implement control measures before it is too late!

Still others, including the variable annuals *Juncus bufonius* and *Schoenus apogon*, may be a mix of both native and introduced versions of these species, while the jury remains out on *Ludwigia peploides* and *Berula erecta*. Most dubious is fountain grass (*Pennisetum alopecuroides*), which seems to have spread quite rapidly in eastern Australia after it was first recorded around Sydney, soon becoming a noted weed in places where it had certainly not been found earlier. Worse still, most plants being sold under this name until a few years ago were *P. setaceum*, a known introduction and thoroughly naturalised weed.

Plant selection – choosing suitable combinations

Customised plant schedules for created wetlands, dams and restoration work are often poorly compiled, showing little knowledge of the plant guilds found in undisturbed wetlands, or their uses, and still less effort at selecting suitable plant combinations for specific purposes. In many cases, they are simply a random selection of species known to occur in wetlands in the area. There is no recognition of their very different needs, or awareness that some plants are not found together in nature because they kill each other off, as will be discussed in Chapter 6.

I call this the 'Mallee With Treeferns' approach to wetland plant selection, and although there is a certain black humour in some of the more outrageous combinations, it is unusual to see more than 10 to 12 species surviving out of a planting list of as many as 50 or 60 on such sites. In part, this is because of the problems associated with raw terrestrial soils in new wetlands (also discussed in Chapter 6).

Other planting lists may border on the ridiculous. At one time it seemed that one or two species on every list I saw did not exist, and never had; one even included a South African succulent that grows only in extreme desert conditions. Similarly, a list of frog habitat plants recycled many times by a particular landscaper included a dozen species that only grow in places where no frog could survive.

Some schedules betray the provenance of the list-writer rather than the plants. In one case I recognised the source as being Tasmanian, because several species widespread in that State were included for the Otways in Victoria – even though they weren't found within 300 km of the area to be planted. This isn't a dig at Tasmanians; it was the only example of its kind devised in that State. However, I have seen a number of planting schedules listing Sydney plants recommended for places up to 1000 km away from their natural range!

A further complication in preparing appropriate planting lists is that knowledge of what grows in many areas is restricted to the plants there today, often the weediest and toughest survivors to come through two centuries of wetland drainage, grazing and increasing salinity. Historical research and study of comparable but relatively undisturbed wetlands in the same general area are needed to come up with more complete lists, or we may end up reducing biodiversity, replacing it with duplications of the impoverished ecosystems created over the last 200 years instead.

Haphazard lists are a common feature of projects with poorly defined goals. As emphasised in Chapter 2, it is the goals that should decide the design and construction of the wetland itself, as well as the selection of plants. The plants to be used should also shape and define the nature of the wetland. These points can be brought into sharper relief by considering the major criteria that are usually used to justify the creation or restoration of a wetland.

Water treatment

Water treatment is often stated to be a goal in created wetlands, but the random use of indigenous plants will not necessarily make a great difference to water quality. This is partly because few useful studies have been done on the water treatment qualities of the plants themselves. One which still sticks in my mind suggested that the entire genus *Myriophyllum* has little value in water treatment, but does not even specify the species tested, or how they were planted. Indeed, from the vague information given the plants used may just have been dropped into the water, and not been planted at all.

Perhaps the greatest single problem for water treatment is excessive dependence on overseas sources of information, almost entirely from the Northern Hemisphere. This creates a subtle trap, because most of the genera used there are also widespread in Australia, and many of their species are closely related to or regarded as synonymous with indigenous plants. These are used overseas because they are native and readily available there, and easily propagated in climates which are far colder than any Australian ones, but not necessarily for any other reason.

Yet such plants are mostly winter dormant, so their nutrient uptake comes to a halt for a significant part of the year. They are certainly not the species we should be concentrating on in Australia, where many evergreen species with considerable potential continue to be ignored, even though they may actively take up nutrients throughout the year. Worldwide, only an estimated 1% of all plants which may be useful in water treatment have been tested even now.

The plant lists in Chapter 6 include my own assessment of nutrient-responsive indigenous plants from 30 years of practical experience. These grow rapidly given high nutrient levels, sometimes to much larger sizes than any plant of the same type recorded from the wild, suggesting that they not only benefit from sources of additional nutrient, but that they are also actively using it up.

'No net loss' wetlands

This is an idea that has been lurking around for a long time, and reappears in new guises every few years. The idea here is that yet another natural wetland is to be drained – however, a similar-sized area will be created and planted, or allocated for restoration, so that overall wetland diversity and health will not be reduced any further.

This concept may work reasonably well for degraded wetlands that are largely colonised by common species, or that have been accidentally created by road diversions, drain extensions and similar works. However, it is nothing but a joke for any diverse, natural wetland with an established community of plants and their associated animals, because we don't have the ability to restore or replant many types of natural wetlands. And may never have.

Planting for habitat

More than a decade after the first edition of this book came out, most plantings carried out specifically for habitat continue to be poorly planned, carried out and evaluated, assuming that they are evaluated at all. The considerable range of problems, clichés and misinformation that beleaguers many of these ill-conceived wetlands is beyond the scope of this book, and are dealt with in more detail in a companion volume, *Wetland Habitats*.

Edible wetland plants

Strictly speaking, wetlands for production of edible water plants fall under the umbrella of aquaculture, the goals of which have little to do with conservation of any kind. As plant-eating animals of all kinds are unwelcome in such highly specialised wetlands, designed to produce specific plants in a monoculture situation, readers should see my book *Edible Water Gardens* for more information. This covers the cultivation and uses of all aquatic and water's edge plants grown or harvested from the wild worldwide. It is interesting that fully a quarter of these are indigenous not only to South-East Asia, but also native to parts of Australia.

5

Seed collection and propagation

Drained wetlands often retain a viable seed bank buried in their soil, some of which may still germinate decades later if the wetland is restored. However, for many restorations, and for all newly created wetlands or dams, plants must be propagated and introduced. Some are readily grown in large numbers from seed, while others are more easily multiplied from cuttings, divisions, tubers or spores. Methods that work best for the diverse plant groups are discussed in Chapter 7, while the various ways of propagating wetland plants are explained here.

Natural seed banks or planting?

If a wetland is to be restored on a site drained not all that long ago, there may still be a seed bank of the original flora lying dormant in the soil, and pockets or deeper pools in the area may even hold living remnants of the original flora. Salvaging these should be a priority wherever possible, if necessary shifting soils or plants to a temporary nursery area so they won't be drowned as water levels rise.

The only disadvantage of this method is that the dormant seed bank may include non-native weeds, quite a few of which grow and set seed very quickly even under less than optimal conditions, and these are likely to overwhelm indigenous seedlings in the new wetland. The time a wetland has been drained is also a factor, as the diversity of the seed bank reduces with time as seeds age and die without germinating, so that after 20 years it is unlikely that much of value will remain.

In new wetlands there is no hidden seed bank, and plants will need to be deliberately introduced, so that they can establish ahead of the weedier species that are most likely to arrive and colonise the exposed soil. This has sometimes been done by transplanting from other wetlands, and although this method is quick it is also the most expensive option. Most of the more widespread aquatics can be raised in quantity from seed, and for many species the smaller plants that result will establish and grow at least as fast as root-damaged transplants.

Direct seeding is sometimes considered as an alternative to transplants. However, it only works for a limited range of wetland plants (mostly aggressive colonisers) that are easy to establish anyway. It may also be practical for some types of larger seed that germinates readily, although planting must be well spaced in a properly prepared seedbed to ensure reasonable germination and establishment. Seed that is slower to start growing is usually fussy about germinating at all, coming up sparsely and erratically, and these seedlings will almost always be swamped by other plants before they have had a chance to establish.

Collecting and cleaning seed

For many wetland plants, seed is the best and fastest means of propagation if it can be collected in quantity and grown in ideal conditions. Permits are needed for the collection of native plants and seeds on public land, and some species are completely protected, so it is essential to check with your State or Territory authorities for current laws, permits and restrictions. Collecting from private land can be done with the owner's permission, but there are further restrictions in some States; again, check with the relevant authorities first.

Collecting is not always a pleasant job, and you need to be aware of some of the hazards particularly associated with wetlands. The most constant of these is that you will inevitably spend many hours out in the sun, so a hat, skin protection and good sunglasses are essential. If you are working near water, ultraviolet light is reflected *up* at you as well as shining down, so a hat by itself won't be enough to prevent sunburn.

Other ever-present but less obvious hazards are associated with mud, and range from botulism to various infections, some of which are potentially lethal or, at the very least, hard to cure. Rubber gloves give reasonable protection when working in a potentially contaminated environment; alternatively, you need to scrub hands and fingernails thoroughly after contact with mud.

Mosquitoes carry various serious and debilitating diseases and are abundant around some types of wetlands, so protection against these is recommended, but keep in mind that long-term use of insect repellents isn't necessarily any better for the health than the diseases themselves. Larger leeches can cause a nasty bite with symptoms of bruising and secondary infections that may take months to heal. Some aquatic bugs, particularly backswimmers, have a nasty and long lasting sting, but will only use this if handled roughly.

Many snakes including tigers and copperheads are common in southern Australian wetlands because they like to feed on frogs. Copperheads are active even on surprisingly cold days when you would not expect to step on one, so a snakebite kit should be standard equipment for seed collection at all times. Familiarise yourself with the use of constrictive bandages beforehand; these slow the spread of poison into the body, giving you much more time to get to a hospital if applied ASAP.

Waders provide protection against a bite, especially with heavy clothing underneath, but are extremely hot and uncomfortable in the warmer weather when snakes are most active. Hip waders can also be dangerous; if you slip they will fill and tow you underwater rapidly, a common cause of death among duck hunters. They should not be used unless there is someone else (without waders) working near you, or if you can be certain that the area you will be working over is uniformly flat and free of hidden potholes. Thigh waders are shorter, safer and cooler as they can be rolled down when necessary, but they limit your working depth.

On unfamiliar ground, I prefer to wear a surfing wetsuit with diving boots: very stylish, especially with a wet T-shirt worn over the top. This is reasonably snake-proof and also allows you to dip under regularly in hot working conditions. Your collecting kit and seed can be kept high and dry in a foam box with a lid even if you dive under to cool off, as long as you return to shore to offload before it becomes top-heavy and overturns.

It is sometimes necessary to swim as plants aren't always co-operative about growing where you want them to be, so have bathers with you at all times. I once swam a river in an apparently isolated area wearing nothing but a large paper bag (for seed) inside a hat. After 20 minutes collecting in knee-deep water I finally noticed three silent families of campers upstream watching me with alarmed expressions, and still am not sure whether their anxiety was induced by nudity, or my habit of swimming with secateurs between my teeth.

Some sedges and rushes have very sharp spikes to their tips, and if you are collecting among these you will need more eye protection than just sunglasses. Swimming goggles are adequate to protect the eyes themselves, but a diver's facemask provides a more complete coverage of sensitive areas around the eye as well. If you are working among sharp-edged leaves, leather gloves are a must, as even some round-leaved sedges can cause a nasty cut if drawn carelessly through the hand.

Basic collecting equipment includes a pair of secateurs for removing whole seed heads and a large paper bag for each species. Label the bag at the first opportunity you get as soon as your hands are dry – with species, where collected, date, and all other useful information. A pencil will work not only on paper, but also on damp plastic labels, and is much less expensive and less toxic than the supposedly sun-proof felt-tipped pens available.

Sorting and cleaning is best done at a later stage under shade, and will often produce hundreds of tiny spiders as well as seed, so don't try it in a tent you hope to sleep in. Separate seed from the seed heads first, which may require rough handling especially in the case of sedges. Rubber car mats rubbed together with the seed heads between them will loosen much of the seed, but I find that rubbing with a gloved hand (many types of seed abrade or irritate skin) gives faster results for smaller quantities.

After this rough cleaning, the loose rubbish, chaff and seed-eating insects should be separated from the seed. Most commercial operators use a series of fine sieves to grade out larger and smaller detritus, but these are expensive. On field trips, I carry only three kitchen strainers of different mesh sizes (about 1 mm, 1.5 mm, and 2 mm) which do an adequate job for most types of basic cleaning. These are widely available, although you may need to shop around to find all three grades.

Even after sieving, there will usually still be some rubbish of a similar size to the seed. This is mostly lighter than the seed and can be separated by winnowing: putting the mix in a fairly deep bowl and gently tossing it up and down in a breezy place. On a still day, you can speed things up by blowing gently, and this may help even when there is already a natural breeze.

The smaller the seed, the slower and more gently you must winnow at the start. With a little practice you will find the right combination of tossing and air movement for each different type of seed. However, if you are careless you can lose all the seed in seconds. Properly done, winnowing is a very effective process, and it is a delight to watch the stream of pure seed emerging from an unappealing mass of chaff, dust and debris.

Seed production in nurseries

Producing your own seed in a nursery reduces travel time and associated expenses (both financial and environmental), and allows harvesting at the optimal time rather than having to return to a site where seed is not ready at the expected time – or arriving once all of the crop has already fallen. This involves growing a group of plants to a mature size, in ideal conditions so they will produce maximal seed crops from the smallest area possible, and is an excellent option for any nursery with a specific, regional focus and limited time.

How large this group of plants needs to be depends upon the amount of seed you will need on a regular basis, but genes are the main concern for seed production. For maintenance of diversity a minimum of three different sources for each species should be maintained, collected from within a well-defined area as discussed in the previous chapter. This could be a catchment, a set of wetlands within a certain radius, or from a specific type of wetland.

If more than three separate populations are available, better still, and each population should be represented by two or three different clones in the hope that between them these will carry the full range of variability at that site. It is better to crowd more clones and populations into an area large enough to produce all the seed that is needed, than to spread out a smaller number of plants more thinly in the same space. The aim in nursery seed production is not to maximise production from any one plant, but to maximise cross-pollination of plants from within the targeted area.

Growing from seed

Seed ready to germinate (sprout), or which can be triggered into germination by diverse means is referred to as viable – in plain English, growable. As it ages, it becomes increasingly less viable because the embryo contained in the seed uses its nutrient reserves to keep alive, however slowly its metabolism ticks over. Near the end of its viable lifespan, it may germinate regardless of the conditions it has been stored under, because it recognises in some way that this is its last chance to become a living, growing plant.

Seed of wetland plants is usually sown *on* to (not buried in) wet soil in a container standing permanently in water, and this is sometimes described as the 'bog method'. A pot or tray set so that the water is at the soil surface, will be waterlogged. If the water level is a long way down, the soil *above* that level will be moist to wet only. An easy way to keep the water level constant for any species is to sow into foam trays (often given away by greengrocers) (see Colour Plates 10b, 12a), as these float at a constant level so they are self-watering when adrift in a pond.

Seedlings germinated and grown with full light and air movement at all times, and with plenty of water at the roots are unlikely to be damaged by direct sun. By contrast, sowing in shaded conditions may result in rather lank growth, and adds the unnecessary complication of a hardening-off period to adjust the seedlings to more intense light.

A sheet of glass placed a few centimetres above the soil will keep humidity high if this is needed and the plants (for example ferns) are in deep shade; sunlight would cook any seedlings under a glass cover. A cover can also be used to prevent fine seed from being scattered by rain before it has germinated, although a sunlit place under a canopy or in a greenhouse will provide all the rain protection needed.

Seed of submerged plants should be sown in trays in shallow water, 5 cm to 10 cm deep. This should be reasonably warm to very warm for good germination (depending on species), and should be as clear as possible for best light penetration. If the water turns green or brown, it should be changed as soon as the seed can no longer be seen from above, replacing it with water of a similar temperature. Submerged plants should only be moved deeper gradually, as they grow large enough to stay near the surface where the light is brightest.

Many wetland seeds need light to germinate, and the 'buried alive' method of planting has given some an undeserved reputation for being difficult to grow. Their response to light (or the lack of it) makes biological sense. If they are buried deep in mud or in murky water, they do not germinate, but if disturbances such as flooding strip back the covering soil or move the seeds to shallower waters, they will germinate as soon as they detect enough light. Light-responsive seed nearing the end of its viability will germinate even in darkness as it is running out of stored nutrients, and has nothing to lose by sprouting in the dark.

Sedges are an example of plants with seeds often needing light for good germination. Sedge seed which is stripped from the plant before it is completely ripe may germinate if kept reasonably warm and wet, even in the dark. This presumably forces it to grow as an emergency attempt at survival, as it is not mature enough to survive drying out. However, timing of the harvest is critical for this method, and requires some experience.

If in doubt when sowing wetland seed from any new source, plant it on the surface, with protection from sparrows and other seed-eating birds. A sparse layer of soil over the seeds may allow enough light through for germination as well as protection from birds, although this may slow the process down or make it more irregular. Very fine seed should not be covered at all, but should be mixed with fine grades of sand (for example, silver sand or hourglass sand) to help spread it out evenly during sowing. This is particularly important if the resulting plants are to be planted out bare-rooted when they are large enough, rather than pricked out at an early stage and grown on in pots.

Timing and season can be important in planting. The seed of winter dormant species often has an in-built dormancy period, and will not germinate until around the same time as mature plants of the same species start into growth. Although such seed can be sown immediately, there is an increased risk of it being invaded by other species seeding nearby before it begins to grow, so it is usually best planted out closer to its peak germination season.

Some wetland seed is very difficult to germinate, or even apparently impossible with the methods presently used. *Baumea* species are a prime example, many of them producing copious amounts of what looks like healthy, viable seed with an apparently perfect embryo inside. Yet germination reports are scarce and contradictory for some species, and no one has had any success at all with others. Some stands do not produce viable seed, which may reflect a cross-pollination problem (as discussed earlier).

It may be difficult to obtain fertile seed from some clones even when pollen from another source is available, which suggests that other factors such as fungal infections or adverse growing conditions may be playing a part. When seed is copiously produced but seedlings are rarely seen in nature perhaps this means that little of it is intended or expected to germinate?

Baumea seeds are relatively large and heavy: they will float but certainly can't be spread by wind. Unlike the seed of some other sedges, there is no sign of barbs to hook onto fur or feathers. Yet most *Baumea* species are widespread across much of Australia and even well beyond, suggesting that they may be adapted to travel in the gut of birds.

The combination of abrasion and digestive juices might well destroy most of these seeds, but it would only take one or two to come out pre-treated and ready to grow to get the species to new places. Perhaps the bulk of the seed produced is only intended to attract birds for a good feed, and only a few particularly hard-shelled and mature seeds are 'expected' to survive the digestion process and the trip to another wetland, where they would germinate in the ideal, nutrient-rich environment of a bird dropping.

Seeds of some native *Potamogeton* species are known to have survived passing through the intestines of living ducks and have germinated afterwards, although the bulk of them are broken down and digested. Similarly, I have observed occasional *Gahnia sieberiana* seedlings sprouting in parrot droppings, which were tagged after the parrots were seen feeding on the bright red seeds. Most of this seed must also have been destroyed and digested.

Whatever the cause of unexplained germination problems, it is obvious that we need to learn more about what would happen to such seeds in nature to find solutions – or at least explanations. Some experiments are more obvious than others, for example testing the effect of smoke on germination for plants from fire-prone habitats. While not relevant for most wetland plants, at least two genera of cordrushes from Western Australia seem to sprout more liberally after smoke treatment, and one of these is a true wetland species.

Seed that is not going to be planted immediately is usually stored in a dry and cool place, as for most terrestrial plants. Dry storage seems to work well for many wetland species, but may shorten the lifespan of others. This is already well documented for some exotic aquatics, and at least a few natives. The expected viability for many wetland seeds stored cold and dry is generally only two to three years for reasonable results.

Yet wetlands that have been drained for decades and then been re-flooded have shown that quite a few wetland plants may germinate 20 and sometimes even 30 years later, though these have probably survived under exceptional circumstances. This also suggests that if you need to store seed with a reputation for short viability, keeping it cool and dark in water or moist soil may be the best storage method. Even the seed of a few tropical waterlilies (*Nymphaea*) and their warmth-loving relatives can be treated like this, so it is likely to be appropriate for at least a few other aquatic and water's edge plants.

Cool, dry storage remains the simplest and most effective option, and may even be necessary to trigger germination. It is believed that some types of seed coat are designed to split when wetted after a prolonged dry period. Many *Nymphoides* species respond in this way, with a carpet of seedlings appearing in a newly flooded pond even if the parent plants have been killed by drought.

By contrast, the seeds of some forms of sacred lotus have a thick seed coat which must be filed through to the embryo to trigger germination, or they will lie dormant for decades if left to themselves. This is one seed which is indifferent to dry storage; there is even some evidence that natural germination of the dry seeds may improve after a century or so!

Other types of propagating material

Nearly all plants that can grow both below water (submerged) and above it (emergent) are most readily propagated in their emergent growth phase (see Colour Plate 11a). This is because they form firmer, more compact tissues above water, have better access to oxygen at night, and are less likely to be damaged by handling. It is also the preferred production method in the aquarium plant industry worldwide, which produces many millions of plants annually.

If submersed materials are transplanted, they must be kept quite wet at all times during handling before they are planted back under water. Emergent propagation materials can be planted just under water, or above it, growing readily in either case as long as a generous water supply is kept up to their roots. Examples of very different-looking submersed and emergent growth in the one species can be seen in many *Myriophyllum* species, or in floating-leaved *Potamogeton*. Plants that only produce floating surface leaves should be treated as submersed material.

Turions (dormant buds), tubers and other underground storage organs are usually formed as a response to falling water levels or cold, depending on the plant species. They are an easy way to transplant species with minimal losses and do produce mature plants quickly, but digging them up can be a backbreaking job. Make sure that they are planted more-or-less the same way up as they grew originally or they will waste valuable stored energy re-orienting themselves.

Cuttings and layers are easily taken from many sprawling or running aquatic and water's edge plants, and re-root readily in most cases. Rooting hormones are rarely required for these plants, except for woody cuttings taken from a few riverine shrubs and, even for these, applying a little heat from below may help trigger new growth.

Massed cuttings of *Myriophyllum* and *Crassula* used to be established on fibrous mats that were then planted out by staking or weighing down with rocks at an appropriate depth. However, their roots rarely anchored through the fibre into the soils below, and as the mat decayed chunks would peel away, taking the plants with them. The mat was unnecessary anyway, as nearly all such species form a tangle of roots when packed together in shallow water. These plants will grow roots over a thin layer of nutrient-rich soil only millimetres deep, as this is really just a place for the roots to anchor initially.

Division basically means splitting a plant apart through its base (or crown). Quite a few species of wetland plants will be set back by division, especially if they are divided and lifted from the field in the same operation. Some such as *Carex appressa* and *Gahnia sieberiana* may be killed by this treatment. Like many other plants which don't respond well to division, both of these are easily grown from seed, transplanting before they have established extensive root systems.

For species which don't set much seed, or set it over long periods of time so that it is uneconomical to harvest, division may be the simplest method of nursery propagation. Plants like this are relatively expensive to produce, although their cost is reduced if they are kept in pots and split regularly, over a long period. They should be planted with special care for each individual plant, so that they will mature and set seed relatively early in the life of a new wetland, before other plants move into their potential growing sites.

Rhizome cuttings are taken from the runners and underground stems of plants, producing new growth from nodes and joints. In actively growing plants there will usually be obvious buds or new shoots at these points. Dormant rhizomes are best cut just as they start their growth stage, or they may rot away from the cut end before the tips have begun to grow.

Missing mycorrhizal fungi may be the answer in some cases where plants cannot be raised from seed easily. These fungi are associated with the roots of diverse groups of plants, some of these fungi with only a single species, others with a wider range. What all mycorrhizal fungi do is improve the efficiency of nutrient and water uptake by plant roots, and in return the plant produces (or leaks) sugary compounds the fungus benefits from. Some plants won't grow well without them – for example, seedlings of *Melaleuca symphyocarpa* germinate easily but are far slower growing than the same species grown from root cuttings, which have the right mycorrhizal species already attached.

Saltmarsh plants follow rules of their own, and surprisingly these don't necessarily require the slightest trace of seawater. Seed is a nuisance to collect for the more succulent species as it is hard to gather in any quantity, but they will mostly grow easily from cuttings watered with fresh water. A few will benefit from salt water in small amounts, apparently because this acts as an anti-fungal agent.

At another extreme, most wetland ferns can be propagated from spores (see Colour Plate 11b). These are very different from seeds as they have no nutrient store to start them off, and they also go through a specialised (and tiny) reproductive stage before the fern is produced. All this takes time, so ferns are easily overwhelmed by faster growing plants if the medium they are grown in has seeds present as well. A sterile medium is essential if large numbers of ferns are to be produced from spore, although plantlets will appear around the parent plants spontaneously in some species.

Substantial numbers of many wetland ferns can be raised in finely sieved peat moss that has been wetted thoroughly, though not to the point of waterlogging. Their spores should be spread evenly in a container with a clear lid (take-away food containers are good on a small scale, glass-topped aquaria on a larger scale), then sealed and kept in bright light but out of any direct sun. During hotter weather the containers can be floated in deeply shaded ponds to keep temperatures more uniform, the tiny ferns should be ready for separating and growing on in pots within 12 to 18 months.

Soil, fertilisers and water

Natural wetlands become increasingly fertile with time, as nutrients are washed in from the terrestrial systems surrounding them, or even arrive dissolved in raindrops. There are still some rice paddies in Asia which have not needed fertilisation in centuries, though this is changing as more crops are forced each year. A newly created wetland is very different, and nutrients of various types must be added to the soil if a reasonably diverse range of wetland plants is to succeed.

Soils and water requirements for propagation are much the same as for planting out, discussed in the next chapter. However, the soils used in a nursery situation can be made richer in nutrients for faster initial growth, and of course these must be fairly sterile to avoid competition from weed seed. Most nutrient-free commercial potting mixes make a suitable starting point for wetland seed mixes made up on a small scale, or if you have a soil-sterilising kit you can use almost any loam-rich topsoil instead.

Nowhere near as much soil needs to be used for propagation as in the wetland itself, so relatively expensive 'ingredients' can be added to create soils that more closely approximate true wetland conditions, as opposed to the raw, terrestrial topsoils found in nearly all new wetlands, and which are discussed later. For example, I use up to 5% vermiculite (heat-expanded mica flakes) in many of my nursery mixes, because this retains a substantial reservoir of water so that drying out is less of a problem on days of extreme heat. Peat should not be used for this purpose as it is very difficult to re-wet once dry, its harvest destroys some types of wetlands, and it is largely imported and rarely entirely sterile.

Blood-and-bone is probably the best all-purpose, slow-release fertiliser for wetland plants and won't damage roots of less salt tolerant species as synthetic fertilisers sometimes do. This is basically a finely ground, dried, nitrogen-rich abattoir by-product, added at anything from 0.2 litres to 10 times as much per 100 litres of seed-propagating mix, depending on how heavy a feeder the plant being grown is and how long it will be left in the original mix before repotting.

Soluble chemical fertilisers are not formulated for aquatic use (the market is too small for the larger fertiliser companies to bother with), and their components are used in unpredictable proportions by wetland plants, so unused components of what they contain leach out into water instead of being absorbed. These synthetic fertilisers are basically a mix of inorganic salts, which many wetland plants don't appreciate, so some stress is probably caused by their use even at low concentrations. Many of them include soluble sulphates which convert to hydrogen sulphide when flooded (rotten egg gas, toxic for plants and animals), and damage roots of more sensitive wetland species.

You don't need big science to recognise the differences in growth and pest-resistance between wetland plants fertilised differently. A simple test of seedlings of the same species, grown side by side in otherwise identical soils with blood-and-bone in one batch compared to chemical fertilisers in the other, usually shows different tolerances to insect attack. Aphids in particular can become a problem with the use of synthetic fertilisers, which is not surprising as they are attracted to softer or more elongated plant tissues.

The most obvious effects of salts (including in the form of fertilisers) only appear at increasingly high concentrations, and at levels no one would think of applying as fertiliser. Hard or saline waters have similar effects, reducing flowering and general vigour once salinities reach 2000 to 3000 parts per million (ppm). This relatively simple measuring system is used here because it is much easier to grasp than conductivity readings, which are an abstraction to anyone who doesn't use them on a regular basis.

By around twice this concentration, most species of freshwater aquatics will either be dead or obviously unwell. Tolerance to salinity varies considerably; moderately salt-tolerant species appear healthy, flowering and setting seed at concentrations up to 1500 ppm, or even 2000 ppm. Very salt-tolerant plants (as opposed to the much more tolerant saltmarsh species) are apparently unaffected at levels from 3000 to 4000 ppm, although this may vary with their seasonal cycles.

As a general rule, salt (sodium) tolerant plants are also tolerant of comparable figures for water hardness, which is the measure of the calcium and magnesium ions present. Hard waters are also often quite alkaline as well, with a pH well above 7, the neutral mid-point from which acidity and alkalinity are measured.

The pH of water is not as important as that of the soil, so plants that don't like alkaline water may grow well in an acid soil even if their water is moderately alkaline. This is an area still needing considerably more study, but as a rough guide most aquatic plants grow well at a *soil* pH of 5 to 7, which is mildly acid to neutral. Some look well and apparently grow healthily at a pH as low as 4, and the most rugged survive mining wastes at pH 3 (though it is doubtful that they are living happy and fulfilled lives at this level).

At the other extreme, estuarine, inland and salt-tolerant plants often grow in alkaline soils. Although the upper limits for these are not known in most cases, few are likely to thrive above a pH of 9. Plants tolerating a pH of 8 (or sometimes a little more) are noted as lime tolerant in the plant information chapter.

The soil conditions of plants being propagated should be matched reasonably closely to those in the wetland to be planted, to minimise any shock during planting out. If there is likely to be a marked change in salinity, hardness or pH of the water during planting out, plants should be acclimatised to this beforehand. Dormant tubers are not usually as obviously affected by changes, other than to soils and waters outside the limit of their natural tolerances.

6

Planting out and problems

Although issues such as water quality and fertilising are not qualitatively different at the planting out stage, soils in a newly created wetland are very different in their nature from those that have built up under water over centuries. Another aspect that changes radically when propagated plants are shifted to their new home is that they are suddenly exposed to damage by waterbirds and vermin, to competition from colonising weeds and from incompatible species used in the same planting.

Why only a limited range of plants succeeds in new wetlands

Wetland soils are very different from terrestrial soils; after all, they have often had centuries or even millennia of the best topsoil and nutrients from the surrounding lands washing in, forming a fine silty layer that is rich in organic matter. What we harvest from the uppermost layer of terrestrial soils and call topsoil is very different, and flooding this sets off a series of chemical changes with associated instability which will take months to settle down.

During this time, the pH of recently flooded soils drifts increasingly towards neutral, compared to a wider pH range found in diverse types of terrestrial soils. The tiny, remaining pockets of oxygen within the newly flooded soil are used up rapidly, usually within several days, after which soluble forms of iron and manganese are released. If the flooded soil was quite acidic to start with, this process may accelerate as the pH rises, and quantities of ionic iron may reach sub-toxic levels for rooted plants, as well as trigger algal blooms.

With the oxygen gone, anaerobic decay of organic matter also begins to release ammonia, hydrogen sulphide, and various organic acids including acetic (vinegar) and formic (chewed ant flavour) acid. These are one reason fishes and most other aquatic animals should not be released into recently flooded wetlands, although the lack of food and shelter does not help either. On the plus side, significant amounts of organic matter reduce the potential problem of metal toxicity; as the organic matter breaks down, it locks away metal ions – this is why metal toxicity is usually at its worst where flooded subsoils with little organic matter are mixed inadvertently with topsoils.

All of these things combine to depress growth rates of plants in recently flooded soils and, in the case of more sensitive plants, to kill them off altogether. These processes take anything from 4–6 months to reach a final, stable stage, though they are usually approaching a stable condition by around three months. Such soils are still a long way from true wetland soils (which build up over the surface of the flooded soils after still more time), but a wider range of plants will be able to grow in them.

This is why a list of 30 or 40 species to be planted all at the one time in a new wetland is a waste of time, money and effort – and also why a limited range of adaptable colonising plants takes over most created wetlands fairly rapidly. It is possible to create more diverse wetland plantings, but *only* by staggering plantings so the colonisers initially introduced are followed perhaps six months later with a wider array of reasonably adaptable species, and after a minimal time of 12–15 months by some of the more specialised species (see Colour Plate 12b). Of course, this assumes that the plants themselves are compatible, as it is becoming increasingly clear that many of them will wage war on each other, and the survivors are all too often – the colonisers.

Plant interactions

Overseas, an ever-expanding range of studies is revealing allelopathy (or antagonism) as a widespread adaptation among water plants, which affects how well some will grow in the company of others. In a broad sense allelopathy refers to chemical defences against both animals and plants, but in created wetlands we are mainly concerned with the effects plants have on each other.

Allelopathic wetland plants use a wide array of chemicals against potential competitors, from simple organic acids to more complex poisons such as alcohols, tannins, alkaloids, sulphides and even long-chain fatty acids. Most species probably only have a limited arsenal of up to around half a dozen chemicals they release into water, or into soil through their roots, to deter other plants.

As most of the study in this area has been done overseas, not much is known about which Australian plants use allelochemicals; though it is not hard to guess. Some *Eleocharis* species definitely eliminate competing plants, which is probably why they are often found in dense, single-species stands. Several exotic

Myriophyllum have also been shown to effectively reduce growth in a number of other plants with the help of cyanogenic compounds among others, and it is likely that at least some of the larger Australian species do so as well (see Colour Plate 13a).

Other Australian aquatics must also be toxic if their close relatives are any guide, ranging from *Brasenia*, *Ceratophyllum*, *Hydrilla*, and at least some *Juncus*, to *Nymphaea*, *Potamogeton* and *Vallisneria*. The native *Bacopa monniera* produces only nicotine as a deterrent, while a relative of our native *Posidonia* is known to use around a dozen complex chemicals in its quest to form single-species stands!

There are undoubtedly many more species to be added to this brief list, and without even studying the compounds they produce, allelopathy can often be confirmed simply by growing suspected species with a range of possible competitors. Not all of their toxins will necessarily be produced at all times; the plant must expend energy to produce them, so some may be formed only in response to an animal feeding on the plant, or to competing plants. Effects on other species may only become evident at this time.

Some of the most toxic allelochemicals are produced by algae and their relatives (blue-green 'algae' are particularly well known in this regard), and it is believed that most types of algae use chemical weapons against each other in various ways. Although their effects on other plants may be incidental to their wars with each other, in a new wetland with high nutrient levels, a rapid proliferation of algae may reduce the range of wetland plants that can continue to survive there.

Walstad (2003) provides a good literature survey of allelopathic interactions in wetland plants.

Soil texture and cost-effective additives

It is uneconomical to try to imitate mature wetland soils, and the best we can hope to do is create artificial soils that will provide an adequate substrate and nutrient in the short term, until natural processes have taken over to build up something closer to the real thing. The chemical processes that take place in freshly flooded terrestrial soils have already been discussed, so this section concentrates on ways to imitate wetland soils more closely, and possibly hasten the maturing process.

One of the most important qualities for artificial wetland soils can probably best be described as texture – the soil must be reasonably soft and penetrable by plant roots. This is not a problem in many topsoils, but if only clays are available these should be broken up to at least a soil depth of 5 cm for shallow water and water's edge species. Ideally, this breaking up would be in two parts, an initial ripping that leaves fairly coarse clods, and a second, more thorough job a few weeks after flooding (which will also help speed the changeover from terrestrial to submerged soil).

Timing is important here; if broken up too long before the wetland fills, clay may have time to re-compact to some degree. On a large scale, the finest, softest and most silt-like conditions can be created with some types of rotary-driven and tractor-driven hoes, once the roughly broken clay has been shallowly flooded. Shallow water and submerged plants particularly benefit from these softer soil textures.

The addition of nutrients, organic matter, sand and similar materials will help to keep clays porous for longer, and will speed up plant growth. Cost and availability are the main factors in choosing these; for example spoiled straw, crushed brown coal, and even rock dust from basalt or granite may be suitable additives if they are inexpensive locally, and are compatible with or complementary to existing soils.

These should be incorporated with the initial ploughing up of the clay, and even a bulldozer can work them in reasonably thoroughly if the operator is skilled. Straw is one of the most readily available forms of organic matter, and though it takes its time in breaking down underwater it does seem to change the nature of recently submerged soils in a useful way. Barley straw has a reputation for suppressing blue-green ‘algae’, but this seems to have become a new sort of superstition in recent years, and I have yet to see concrete evidence of its usefulness in this regard.

Volcanic clays have most mineral nutrients needed in a wetland, though the addition of nitrogen in the form of blood-and-bone to these will speed plant establishment. This can be thinly spread over the area, then covered with the planting soil to minimise nutrient leaching into the water. Soluble chemical fertilisers should not be used for the same reasons as in nursery propagation. The use of these may explain why some plants sometimes over-run others at an unexpected rate in new plantings, as more salt-tolerant species have an advantage over those that respond negatively to chemicals they are not adapted to.

Livestock (particularly sheep) have been discussed earlier as a possible means of compacting and sealing clay soils in a new dam or wetland. Although it is usually recommended that they should be fenced out once a wetland is first filled, their trampling and manuring in shallow waters may accelerate soil maturity, making it more suitable for a wider range of plants than will grow in raw terrestrial soils.

Staggered plantings

Planting of most wetland and aquatic plants is often done in shallower waters than they will occupy later, as they will spread themselves deeper into their natural zones as they establish. Submerged plants may need to be planted *much* more shallowly initially, because the water in a newly developed wetland or dam will often be murky, and there may not be enough light for them to grow deeper at first.

Ideally, water levels in a newly planted wetland should be kept at around full for the whole of the first growing season, to allow plants to grow as quickly as possible under ideal conditions. This can't always be arranged, so planting may need to be staggered to take advantage of the natural cycles of both the plants and the wetland planting schedule. For example, autumn-dormant tubers such as *Bolboschoenus* can be planted out long before the wetland begins to fill, so that they come up as soon as conditions suit them.

On the other hand, most submerged plants are probably best left unplanted until the second season. By this time soil conditions should have changed enough for most species, and they can be planted deeper because the water should have cleared considerably. The size of planting material used is also important, as well-developed submerged plants will reach the surface (and brighter light) earlier, so they will establish faster.

Larger plants are also better for shallower plantings, as many shallower-water species obtain much of their oxygen requirement from foliage growing above the surface. Although seedlings and other smaller plants of such species won't necessarily drown if planted too deeply, their growth may be slowed down for months, while a larger plant able to hold its foliage above the water within a few days of planting will establish and grow many times faster.

This is particularly true in recently submerged wetland soils. In these areas, larger plants can import oxygen from leaves already above the surface down to their roots. While the raw soil they are planted in matures, these plants can use their surplus oxygen to offset some of the undesirable effects of dissolved chemicals.

Planting methods

Larger nurseries often produce wetland plants as tubestock (in small pots called tubes), or in trays of still smaller cells which are sown by a machine. One disadvantage of this method is that timing can be tricky if the plants mature before the wetland they are allocated for is ready for planting. Another disadvantage is that excessively vigorous species may be hard to extract from their cell or pot without causing damage to the roots if they have been left too long.

On the plus side, no particular skill is needed to plant tubestock out, and even relatively inexperienced staff will learn the routines quickly. Often a planting team works together, one person with an auger in each hand drilling holes of the right size, another removing plants from tubes and dropping them in, and a third keeping up plant supply and removing empty tubes so the process goes smoothly.

For some species, larger potted plants establish better, and it is also possible to plant these deeper immediately, which has advantages for drought-proofing in a wetland that is expected to dry out by the end of the growing season. In this case, the deeper planting means it takes longer for the drying out process to reach the plant roots.

Submerged species are best planted bare-rooted, as bunches of rooted plants. Trying to plant out large numbers of these in pots is slow and will often result in serious drying out; their soft tissues are also easily broken or torn off if they hang over the edge of a pot. However, most other types of wetland plants are also naturally pre-adapted to bare-rooted planting. This is partly because they can and do replant and re-orient themselves after flood damage, and partly because they must be able to routinely survive long flood periods with little light and reduced oxygen levels, so these species are easily boxed and transported.

Supplying bare-rooted plants offers many advantages for small-scale propagators. These include reduced freight costs (none of the weight of wet soil, or problems preventing slop!), and greater speed and ease of planting. With tubestock, a solitary planter may have to make repeated trips over long distances, lugging heavy boxes of pots over marshy soils that are difficult to walk in.

A foam box with 40 tubes in it weighs many kilograms, but the same box with the equivalent bare-rooted size of the same plant may only weigh a couple of kilograms, yet contain thousands of plants. This ease of handling in aquatic and semi-aquatic plants explains why, among all the world's important crops, only wetland species such as rice and taro are routinely transplanted as bare-rooted seedlings or divisions (see Colour Plate 13b).

The main disadvantage of bare-rooted plants is the time it takes to prepare them for planting out, though this is then offset by the speed with which the planting out can be done. Smaller nurseries also don't need a truck to carry thousands of tubes to the planting site, as the same amount of bare-rooted plants pack so efficiently that they can be freighted even by post, or will fit in the back of a utility or station wagon.

Unless the soil used for propagating, and that of the wetland to be planted are similar, bare-rooted planting may also improve survival of the plants. For example, *Triglochin lineare* and *T. alcockiae* frequently grow in relatively ephemeral pools with a clay substrate. If planted as tubestock, the pocket dug into the clay for the plant effectively traps it in a cup which refills relatively slowly from the surrounding clay, and it may dry out before the roots penetrate the surrounding clay. By contrast, a bare-rooted seedling can be planted by opening a wedge-shaped hole with a narrow shovel in a second or two, and the clay is then pressed back around the roots with direct, immediate contact between the plant and the soil.

Vermin and waterbirds

Protection against vermin is just as important in wetlands as in terrestrial plantings, and the most widespread pest is often the same in both – rabbits. These will even wade into shallow water, trimming plants down to the surface. Fencing with standard heavy rabbit mesh (a little over a metre high) with an outward curve at the bottom discourages digging. In sandy soils an extra panel about 30 cm wide may be needed, pinned down with wire staples until grass grows through it. This should be laid along the ground overlapping with, and connected to, the bottom of the main panel. A finer mesh strip up to 30 cm high may need to be added over the standard mesh where there is a chance of very young rabbits pushing through and establishing a breeding colony on the other side.

As wetlands are usually intended to be a sanctuary for waterbirds and other animals, it may be economical to extend the rabbit fence to exclude foxes as well. A rabbit fence can be made a bit higher using a wider standard rabbit mesh width of 1.5 metres, with the top 30 cm forming an overhang coming slightly out from the posts, to stop foxes from climbing. A 30 cm overlapping panel at the bottom laid as for rabbit fences on sandy soils will keep them from digging through, and is much easier to install than digging in mesh which is usually recommended.

I have used fences like this to protect ducks and poultry for more than 20 years now. Although any bird which escapes over a fence is almost invariably taken by foxes within a day or two, those within have remained safe except on one occasion when bushrats undermined a section of fence. Along sections with softer soil than usual, a double width of the 30 cm mesh along the ground may be advisable. As the grass grows through this mesh, it becomes almost invisible to digging foxes, and confuses them when they try to get through it.

In the water, carp can be very destructive on submerged plants, partly through direct damage and partly through reducing light levels by constantly stirring up the mud. The problems of keeping unwanted fishes out of some types of wetland have already been discussed, but if they can be screened out permanently it will be worth poisoning off any vermin fishes already present. This is usually done with rotenone, a fish-specific poison that breaks down to harmless substances within about two weeks, but which can only be used under permit. A concentration of 0.5 ppm of rotenone will kill fishes in many cases, increasing to 0.75 ppm or more in harder, alkaline water.

Other treatments include agricultural lime (not quicklime) applied at around 100 kg per 20 000 litres of water, to raise the pH to around 9 rapidly, from an initial pH of around 6 to 7. A slow increase may allow the fish a chance to partly adapt to this level, and it may be better to aim closer to a pH of 10 to make sure of a complete kill. Swimming pool chlorine or sodium hypochlorite also work at a concentration of 4 ppm, and will dissipate to harmless levels within a few weeks. Both these treatments will also kill other piscine vermin including plague minnows and redfin. (*Wetland Habitats* includes an expanded section on dealing with vermin.)

The main problem with applying any such treatments is mixing them in as this must be done as quickly and uniformly as possible. They are easier to apply (and less of them is needed) if the dam or wetland already has a drawdown system built in so that the water level can be lowered, or if it can be partly pumped or siphoned out. A fire pump with the hoses used underwater to create strong currents is a simple aid to mixing, as is an outboard motor mounted on something solid in the shallows.

Bird damage

Waterbirds are not welcome in new wetland plantings, and must be kept away from the plants. Even herbivorous native species such as swans and black ducks can undo an entire planting in days, pulling up some plants and eating others, while domestic ducks and geese should be removed or, if necessary, shot. Unfortunately, many wetlands which desperately need planting attract bird-lovers who encourage unnaturally high populations through feeding with bread, and resent any attempt to thin or get rid of them.

The alternative is netting until all plants are established enough that they will tolerate a certain degree of damage. However, this is a balancing act, as large enough numbers of birds will defy any attempt to get plants settled and growing (see Colour Plate 14a). The most efficient method of establishing plants in waters where waterbirds are well entrenched is in blocks, with a freestanding frame over them covered in fruit nets. These nets come in various widths, in rolls 300 metres long which can be cut into shorter lengths as required, and can be reused for many different plantings. However, in rural areas, netting may tangle snakes and individual guards may be a better option.

Some common wetland weeds

Not many indigenous plants apart from *Juncus* species with their prolific seed production, their ability to grow even on raw terrestrial soils, and possible allelopathic properties, are likely to become invasive in created wetlands or around dams unless they have been deliberately introduced. By contrast, there are numerous introduced weeds that will colonise disturbed wetland soils, and the reason they are already here and doing so well is simply that this is their specialty.

The selection that follows is a list of just some of the most common, often widespread, and undesirable introduced weeds already well established in Australia, and likely to spontaneously appear in a new planting. Many of the numerous other weeds that have been omitted are likely to become more widespread with time, and others may already be problems in localised areas but are unfamiliar elsewhere as yet. There is also an abundance of new potential weeds still being sold through nurseries.

Funds and energy for management of wetland weeds are limited, while the plants themselves retain their youthful vigour and enthusiasm for life forever, once they have arrived. For this reason alone, the list of allowable plant imports into

Australia (and not just wetland species) should be reduced to a few hundreds (possibly up to a thousand or so) with little or no weed potential, as has long been done for aquarium fishes.

Appropriate tactics for controlling or excluding weeds vary. If the affected wetland is filled from a catchment with serious and already established weed infestations, it is unlikely that these will ever be completely kept out as new seeds, plants or pieces will regularly be washed in or be carried in by waterbirds. In this case, the most effective strategy is to try to establish dense, indigenous plantings as quickly as possible, so that there are few niches for a colonising weed to get a toehold in. This should be combined with regular patrols for weeds, every month or two if necessary in peak growing season, to eradicate seedlings and smaller plants while the indigenous plantings establish themselves over two or three years.

Other common weeds will come in, no matter what you do, but may only ever become a minor problem among established plants, and these we generally have to learn to live with. However, prompt removal of such strays, so that seed is never set, can sometimes be an effective and permanent cure.

The entries that follow include suggestions on management where appropriate, but chemical cures are not recommended here as these can cause serious problems to the health of wetland animals, and may favour weeds over indigenous plants if the wrong spray is used. Regulations on use of sprays in and around wetlands, and the types approved for use are changing constantly. Check with government authorities (starting with your local council and State agriculture department) for current information and restrictions if this is the only option available to you.

Alternanthera. The introduced alligatorweed (*A. philoxeroides*) forms dense drifts which will float out over deeper waters. It is declared noxious for all of Australia, and has been spread beyond the Sydney to Newcastle area to Brisbane and Melbourne by Asian communities growing it as a food plant. Clumps growing in water have been reasonably successfully controlled by a beetle introduced for that purpose, but it will also grow on drier land where it seems less prone to insect damage. The clone in Australia doesn't set seed, so it is only likely to appear where pieces have been transplanted by accident; don't transplant other species from areas alligatorweed is known to occur unless they are bare-rooted.

Callitriche. Native starworts have largely been displaced by two introduced species of which *C. stagnalis* is the most common. Once arrived, it will regrow from the tiniest piece, and sets seed from an early age. On the positive side, it is rarely more than a minor weed in established wetlands, and is generally too small to either be conspicuous or of ecological significance.

Cyperus. Drain sedge (*C. eragrostis*) has been spreading rapidly in south-eastern wetlands and wet soils for the past few decades, mainly in disturbed areas but appearing even in established wetlands. It is important to keep this species out of new wetland areas wherever possible in the early stages, as it sets seed prolifically from an early age. If there is little time available to dig out newly arrived plants, slash their tops regularly over the warmer months before the seed heads turn rusty-orange and ripen seed.

Elodea. Canadian pondweed (*E. canadensis*) is a fast-spreading submersed weed that can form dense thickets in streams and lakes. It is almost impossible to eradicate once present, but is not usually a problem in relatively undisturbed or stable areas as it is eaten readily by many waterbirds. *Egeria densa* is similar, but generally much sparser and less likely to become a problem, though it is still widely sold as an aquarium plant.

Grasses. Various pasture grasses (for example *Glyceria maxima*, *Phalaris aquatica* and *Urochloa mutica*) have been introduced in swampy, low-lying areas as fodder species. None of them are much good for this purpose as they are unpalatable or even toxic at times, and many of them have (not surprisingly) become serious weeds. It seems bizarre that, quite recently, even more species of exotic grasses were being introduced by some State agriculture departments, while their earlier introductions were being declared noxious!

Although most introduced wetland grasses will invade degraded wetlands and disturbed areas such as drains, they are generally not a problem in established plantings. Exceptions include fog grass (*Holcus lanatus*) which self-seeds freely even among other plants in wet sites, annual beard grass (*Polypogon monspeliensis*) which is a common weed in saltmarshes, and the invasive *Urochloa mutica*, an aggressively spreading species in tropical wetlands.

There are many ornamental grasses with potential claims to being wetland weeds in some situations, but the introduced ornamental pampas grasses (*Cortaderia* species) can change the whole appearance of a wetland, and self-seed readily on moist to wet soils. These large tussocks are usually dealt with by spraying, as herbicide can be targeted into the crown of individual plants rather than spread more widely. The alternative is burning the crown (not just singeing it!) as it is hard to dig out the roots.

Juncus. There are many exotic weeds in this genus, and though most *Juncus* in Australia are native some of these can also become troublesome, depending on your objectives. Among the most widespread of the introduced species are *J. articulatus*, *J. microcephalus* and *J. effusus*, all colonising disturbed ground in ephemeral wetlands or near more permanent waters. It doesn't take more than a few seeds to create a full-blown infestation of any of these troublesome plants, as they can be hard to separate from indigenous species while young, and set seed prolifically quite early.

J. acutus is found around watercourses in drier and often fairly saline areas; its spiny-tipped leaves are dangerous to livestock and probably many other animals as well. It is best to control this serious weed while it is still young, and still easy to pull out by hand. Larger plants can be cut to ground level with a slasher, after which the remaining crowns are not too hard to mattock out, but a patrol for seedlings will be needed for several years to come.

Ludwigia. *L. peruviana* is mainly a problem from Sydney northwards, but has the potential to become a serious weed across much of Australia, especially with global warming. Outbreaks further afield are expected over time, and should be controlled within 18 months to stop them from setting seed, which is produced prolifically. *Ludwigia* forms dense stands that swamp out other plants, shedding all leaves in winter so it doesn't even provide adequate shelter for wetland animals for that part of the year. Broken pieces will re-root when stranded, and this is also one of the few plants whose seeds will germinate, and put out roots while floating.

Control of this species is still being studied; mature plants are probably fairly easy to kill by drying out. A series of wetting and drying cycles over two years may trigger germination in most seeds, and the resulting seedlings are killed by the dry phase that follows. A paper in Brock *et al.* (1994) gives more information on this species and its control.

Nymphaea. There are numerous introduced waterlily species and hybrids in Australia, of which *N. caerulea* in its blue form has been widely spread in farm dams and some other waters, usually deliberately introduced as an ornamental. It should not appear in new plantings of its own accord, but if the odd seedlings are found these can be pulled out easily. It is important to not confuse the introduced species with the 10 or so indigenous species, one of which is found as far south as northern New South Wales.

The yellow-flowered *N. mexicana* can be a serious weed further south, forming dense, choking blankets in deep to shallow waters. This has also usually been deliberately planted, and is still sold as an un-named yellow waterlily in some nurseries. There are named yellow hybrids such as 'Chromatella' which do not spread or set seed, and which do not become weedy in dams. However, introduced waterlilies look ridiculous and out of place where a natural wetland effect is required.

Sagittaria. Despite their common name, some arrowheads (*Sagittaria*) have spindle-shaped or elongated leaves. Several species including *S. platyphylla* with *Alisma*-like leaves, and *S. montevidensis* with arrowhead leaves are scattered in inland waters of eastern Australia, usually only in disturbed sites such as irrigation channels. These may also appear in farm dams and new wetlands occasionally, where they will grow rapidly if left undisturbed. Both can be pulled up readily by hand for small or localised infestations, and a second pulling several weeks later should be enough to remove nearly all the pieces remaining.

Salix. Willows were introduced to control erosion on river banks, after the native vegetation which originally held these together was cleared for grazing! They offer little in the way of habitat to indigenous animals, and cast a deep shade until they drop their lives in a mass in autumn. The branches fall as smaller twigs and, like the leaves, these break down quickly, so streams surrounded by willows support far less invertebrate life than those flowing through native forest. Willow branches break off readily and take root downstream, while the roots of mature trees creep out into streams accumulating sediment until they alter stream courses.

Willows aren't even good for erosion control, as the detritus they accumulate during floods can increase water pressure so much that the trees are torn out of the ground, taking huge chunks of river bank with them. In dams, large willows suck up thousands of litres of water daily during hot weather, in addition to the normal evaporation losses which would be expected (see Colour Plate 6).

Willows can't just be cut down as they will re-sprout, nor can their roots be dug out as this will cause serious erosion during even the most mild-mannered floods. Control methods usually involve killing the tree itself with herbicide while leaving the roots intact; suitable indigenous plants are then established as quickly as possible to hold the river bank together before the willow roots decay away. A few different variations on this have been developed, the most appropriate of which seems to be cutting the tree down, then *immediately* chopping downward pits into the bark of the stump and filling these with herbicide.

Trifolium. Clovers can appear in large numbers on moist to wet, raw soils exposed when a wetland is constructed in a former pasture. Most common are strawberry clover (*T. fragiferum*) in salt-affected areas, and subterranean clover (*T. subterraneum*) which pushes developing seed pods even into clay soils, forming unsightly mounds that smother other plants quite quickly. Slashing before seed set is the most effective control method for the short term, and if plants can be managed this way until other wetland species establish themselves nearby, clovers will usually disappear or at least become much less conspicuous with time.

Typha. Cat-tail (*T. latifolia*) is related to the native cumbungis, but is easily recognised by its bluer leaves, and dark, chocolate-brown, poker-like flowerheads; the native species have much paler, tan flowerheads. This is a widespread and fast-spreading weed in southern Australia, displacing or growing with cumbungi in many places – though the native cumbungis themselves are too weedy for most wetland plantings! *Typha* is significantly weakened by slashing when flowerheads are about to produce pollen, as their reserves are concentrated in the top of the plant at this time, and no seed has formed yet. Following up with flooding or grazing the new growth will weaken *Typha* still further at this stage.

7
Plant information lists

This chapter is primarily a summary of what is known about the propagation of diverse wetland and aquatic plants, tying this in wherever possible with what is known of their biology and ecology. This will aid in experimentation with those species that aren't always easy to grow. It is worth considering the general role or habits of some of the major groups of plants, before looking in more detail at more specific groups and species.

Major plant groups

Sedges (*Cyperaceae*)

The sedges are widespread in wetlands, with diverse species found from the drier fringes to deeper waters. Large or small, those that grow densely or spread to form large stands are important shelter and nesting habitat above water, and provide underwater shelter for smaller animals of all kinds.

In most cases, seed is the best method to produce large numbers of plants rapidly and with the best chance of genetic diversity, although there are problems with some groups as outlined under the individual entries later in this chapter. In general, seed is sown by the 'bog' method: raised for more terrestrial species, waterlogged for the aquatic and semi-aquatic ones. Seed viability of most sedges is usually good for two and often three years stored dry, but some have a reputation for short viability. This is sometimes because their seed has been buried too deeply during planting, as smaller seed germinates best with bright light.

Most sedges can also be divided while in active growth, the main exceptions being tussock-forming plants of drier places which usually have deep root systems. Some sedges produce plantlets at the flowerheads, often instead of seed, or sometimes by germination of unreleased seed. This is called proliferation; the resulting plantlets can be pricked out as in conventional potting, and can even be divided in the process if they are already large enough.

Common names for sedge groups are often misleading – for example, leafrushes (*Cyperus*) are not related to true rushes (*Juncus*), and nor are the twigrushes (*Baumea*), bristlerushes (*Chorizandra*) or clubrushes (*Bolboschoenus*, *Isolepis*, *Ficinia* and *Schoenoplectus*). Buttongrass (*Gymnoschoenus*) is also a sedge and not a grass. See *Baumea*, *Bolboschoenus*, *Carex*, *Carpha*, *Chorizandra*, *Cladium*, *Cyperus*, *Eleocharis*, *Ficinia*, *Fimbristylis*, *Fuirena*, *Gahnia*, *Gymnoschoenus*, *Isolepis*, *Lepidosperma*, *Lepironia*, *Oreobolus*, *Rhynchospora*, *Schoenoplectus*, *Schoenus*, *Scirpus*.

Grasses (*Poaceae*)

Grasses are closely related to sedges, but are more generally associated with drier environments, although there are still many important wetland grasses which may form extensive stands, especially around the fringes. Apart from their obvious utility as shelter, in many cases their seed is also eaten by various animals – even humans (rice is aquatic and also the world's single most important grain crop). In general, grasses are easily grown from seed though this needs a post-harvest ripening period of anything from three months to a year, depending on species. Seed viability will often remain high even after five years or more.

There are hundreds of species of grasses that may often be found in intermittently flooded areas, or around the fringes of more permanent waters. Only the most aquatic of these are considered in any detail in this chapter – see *Amphibromus*, *Bambusa*, *Diplachne*, *Distichlis*, *Echinochloa*, *Eragrostis*, *Glyceria*, *Hemarthria*, *Hygrochloa*, *Isachne*, *Lachnagrostis*, *Leptochloa*, *Leersia*, *Oryza*, *Panicum*, *Paspalum*, *Pennisetum*, *Phragmites*, *Poa*, *Pseudoraphis*, *Sporobolus*.

Cordrushes (*Restionaceae*)

Western Australia is a centre of diversity for the cordrushes that are ecologically important in a variety of habitats there from dry scrub to the fringes of wetlands. There are also a few species in eastern Australia that form dense stands in wet situations. Quite a few species in this family can be found in damp or relatively dry situations; these adaptable types are not true wetland plants and are not considered here. All cordrush plants are either male or female, and *it is essential to have both sexes growing close together* if there is to be any chance of seed setting.

Many cordrushes are difficult or even impossible to establish in either pots or wetlands. For some species this is because they rarely set seed and any that is produced is often short-lived, so in the wild it would germinate rapidly and thrive only in ideal conditions such as after fire. Even some of the wetland cordrushes seem to need fire to clear competing vegetation and to stimulate seed germination, although smoke treatment doesn't seem to do anything towards triggering germination in most of them.

Most cordrushes do not have well-developed rhizomes, so propagation by division will only work reliably for a few of them, and timing this for when the plants are starting to produce new roots and rhizomes is critical. Plants that are already well established in pots are the easiest to divide, as they can be removed from their pots to check for new root growth regularly, making the timing more precise. Genera of wetland cordrushes that can be propagated fairly reliably include *Baloskion*, *Chaetanthus*, *Chordifex*, *Empodisma*, *Leptocarpus*, *Lepyrodia*, *Meeboldina*, *Sporadanthus* and *Tremulina*.

Annual plants (*diverse families*)

Many species and groups of aquatic plants grow for only a few months (at most, a year or so) before flowering, setting considerable quantities of seed, and then dying. These are called annuals, and this adaptation is widespread across many plant families as it is well suited to ephemeral wetlands, ponds, and the broad fringes of larger wetlands which dry out rapidly. Some populations of plants which are usually longer lived may also act as annuals in ephemeral wetlands, for example Austral sweetgrass (*Glyceria australis*), but it is not always clear whether these are genetically different from perennial populations, or if this is an 'ability' built into the species so it can survive in areas with frequent droughts.

Most annuals set large quantities of seed that will remain viable for many years even when dry, though in a few such as *Vallisneria annua* the seed will only survive for more than a few months if the soil it falls into remains moist (or better still, wet).

Because of their nature, it is difficult to transplant annuals as potted plants – timing, soils and the condition of the wetland to be planted into are all critical, and any errors in timing can mean that no seed is set, so there is no new generation. The simplest method to produce annuals is closely packed in trays for maximum cross-pollination, collecting and then scattering the seed in suitable patches of unplanted soil, not long before seasonal rains begin to fill ephemeral wetlands. Alternatively, the entire tray can be planted out at this time, leaving the plants to distribute their own seed.

For genera which include plants that act as annuals, at least in some situations, see: *Amphibromus*, *Aphelia*, *Apium*, *Blyxa*, *Butomopsis*, *Caldesia*, *Centipeda*, *Centrolepis*, *Commelina*, *Cyperus*, *Damasomium*, *Diplachne*, *Echinochloa*, *Eclipta*, *Elatine*, *Eleocharis*, *Epilobium*, *Eriocaulon*, *Fimbristylis*, *Glyceria*, *Gratiola*, *Haloragis*, *Hygrochloa*, *Isolepis*, *Lachnagrostis*, *Maidenia*, *Microcarpaea*, *Monochoria*, *Murdannia*, *Myriophyllum*, *Najas*, *Nymphoides*, *Oldenlandia*, *Oryza*, *Ottelia*, *Panicum*, *Rotala*, *Ruppia*, *Schoenus*, *Tapheocarpa*, *Triglochin*, *Vallisneria*, *Xyris*, *Zannichellia*.

Ferns and their allies (*diverse families*)

Most ferns are water loving, so not surprisingly there are also specialised groups that are always associated with permanently wet and often shaded places, from fern gullies in mountainous areas to the more open, spring-fed swamps exposed to full sun where coral ferns grow. Although ferns are scarce in most types of wetlands, in ideal situations they can be the dominant plants, creating unique habitats and microclimates unlike any others.

Ferns are often propagated by division as this is more convenient than the difficulties of raising slow-growing spores, discussed in more detail in the previous chapter. Raising from spores is not yet an option for some ferns, as the timing of harvesting and planting is not yet understood. However, for others such as coral ferns, division and transplanting are unreliable, so the slower and more expensive process of spore raising is the only commercial option – though this is so usually so slow that most wetland nurseries avoid ferns altogether!

See *Acrostichum*, *Ampelopteris*, *Angiopteris*, *Azolla*, *Blechnum*, *Ceratopteris*, *Christella*, *Cyclosorus*, *Gleichenia*, *Isoetes*, *Marsilea*, *Pilularia*, *Stenochlaena*, *Sticherus*, *Todea*.

Saltmarsh plants (*diverse families*)

Saltmarsh plants come from diverse families, and are only grouped together because of their similar ecological needs. Although salt water is the most obvious of these, it is not indispensable and most saltmarsh plants can be propagated in pure fresh water. Rather, it is their ability to tolerate high levels of salinity that gives saltmarsh plants the edge in saline environments. Many of the more succulent species are easily grown from cuttings, and some benefit from the addition of around 5% seawater to the ponds they are raised in, as this reduces the chances of fungal problems while they are establishing roots.

See *Apium*, *Cotula*, *Distichlis*, *Frankenia*, *Halosarcia*, *Hemarthria*, *Juncus kraussii*, *Malva*, *Melaleuca halmatutorum*, *Mimulus repens*, *Ranunculus*, *Ruppia*, *Samolus*, *Sarcocornia*, *Schoenoplectus pungens*, *Sclerostegia*, *Selliera*, *Sporobolus*, *Stuckenia*, *Suaeda*, *Triglochin*, *Wilsonia*.

Mangroves (*diverse families*)

Mangrove stands are a significant habitat in themselves, becoming increasingly more diverse in both species and communities towards the tropics (see Colour Plate 14b). Their roots are home to a wide range of specialised animals and young fishes, including many that are commercially important. Some are good honey flora, others used for timber, and seeds of some species have been eaten – although appropriate preparation is important. Only five species extend as far south as northern NSW (three of them uncommon there), only *Aegiceras corniculatum* and *Avicennia marina* to around Merimbula, and just *Avicennia* southwards from there.

Aegiceras and *Avicennia* have been most dramatically affected by the spread of what is called civilisation, and are the only species to be propagated on any scale so far. However, the seed biology of many tropical mangroves is comparable, and the same methods will probably be suitable for many of these as well (although little is known about the propagation of species that are non-livebearing). Seeds of these two genera may begin to germinate while still hanging on the parent, and will take root in any deep, silty mud if they are caught there long enough. If the tidal salinity range is suitable, they will thrive.

Mangrove seeds do not thrive in standard pots – these containers are too shallow for the long taproot, but do better in 50 cm or longer sections of 7 cm plastic pipe. This can be cut in halves lengthwise and tied back together before filling with soil, so that the seedling can easily be freed later. It is important to set up the nursery area in the right tidal range (for example *Aegiceras* prefers to be upstream in somewhat fresher waters than *Avicennia*) or growth can be slowed considerably. The planting hole should be augered, and ties cut before the pipe is pushed into the hole for planting as the roots resent disturbance. Seedlings have also been transplanted, though this is an unreliable and often environmentally destructive practice.

See also *Acrostichum* and *Nypa*.

Propagation guidelines

There is no simple definition of what a wetland plant is. If every species that grew on the fringes of Australian wetlands was included here, the following list would be at least double the length, distracting attention from the species and groups that are dependent on at least seasonal flooding, useful in water treatment, and in many cases ecologically important in wetlands.

The artificial dividing line is even harder to draw in northern Australia, where many plants found around the fringe of wetlands during peak flood periods won’t flower or set seed until the rains are over. Many of these are also found on higher ground which remains wet until shortly after the rains stop. For this reason, species that are only incidentally associated with wetlands, and are as likely to be found in drier conditions have been excluded, as have a few plants which are rare, localised or poorly known because they have never been cultivated.

The plant lists below are arranged by genera (plural of genus), followed by the family the genus belongs in. All genera listed include plants that grow in water for at least a part of the year, or around the water’s edge at normal (non-flooded) maximum water levels. Even within this scope, many groups described include numerous and diverse species, and specific species are only mentioned if they need different treatment to the rest of their genus. Detailed species-by-species information on range, habitat and other requirements is available in several books listed in the bibliography.

To save unnecessary repetition, assume that all plants described are perennial unless otherwise stated, will grow in full sun, in silty or uncompacted soils with some organic matter and pH between 5 and 7, in a hardness range from about 50 ppm to 1000 ppm, and that seed life (viability) under cool, dry storage conditions is two to three years. Other tolerances for shade, salinity, clay, and exceptionally hard or soft waters are mentioned where appropriate.

Seed that needs light for germination is recommended to be sown *on* to soil. Moist soils aren't particularly wet, while wet soils may yield some water when squeezed, but there is no obvious dividing line between them. However, waterlogged soils are sodden, and water will fill any hole pressed into these. As waterlogged soils contain very little oxygen, seedlings and roots of any plants not adapted to these conditions will drown.

Exotic plants are not recommended for wetland plantings, and even Australian species are potential weeds if introduced outside their natural range – perhaps even more so than many exotics! Use only species known to occur in the general area of any planting, preferably collected within the same river catchment as the wetland or dam to be planted. However, as has been discussed earlier, there a quite a few wide-ranging species that can 'jump' large distances. It has been assumed that any permits needed will have been obtained before propagating material is collected, including permission from the owners of privately owned wetlands.

Plant lists by genera

Acrostichum. (Pteridaceae) Mangrove ferns are found in swampy situations on the freshwater side of mangrove swamps, usually in fairly fresh waters although both Australian species will tolerate occasional salt water flooding. Where smaller plants are crowded in the shade of their parents, these are usually fairly easily transplanted, but larger plants are unlikely to survive division and should be left alone. Spore can also be raised, though not reliably, as sporelings possibly need contact with mycorrhizal fungi associated with the parent plants.

Aegiceras. (Myrsinaceae) See general remarks under Mangroves, above.

Agrostis. (Poaceae) See *Lachnagrostis*.

Aldrovanda. (Droseraceae) Waterwheel plant (*A. vesiculosa*) is a floating, carnivorous plant forming tangles among taller aquatics, especially sedges. It is notoriously difficult to keep growing in cultivation, but in suitable wetlands establishes readily from divisions (any small piece of an actively growing plant) dropped into clear water where there is little competition from algal growth.

Australian forms vary widely in appearance and growth responses depending on where they have been collected, so provenance is critical.

Algae. Diverse species of algae are present in almost every wetland, and they are often ecologically important. However, they are more usually regarded as a pest, or a sign of ecological imbalance when mats of one or more species form floating clumps on the surface, or the water turns a soupy green from excessive nutrient levels. For this reason, algae are rarely introduced deliberately into wetlands, and in any case many have specialised needs so they will not thrive in created wetlands.

Before waging war on what may be perceived as unsightly algal growth, consider that any over-abundant growth may be helping to improve water quality while other plants establish and spread, and that algae provide shelter and food for diverse invertebrates, tadpoles and smaller fishes. It is only if an algal bloom consistently returns year after year that it should be considered a problem. In such cases work out the reason it is an ongoing problem, for example locating and cutting off the source of excessive nutrients which fuels most green water blooms. This may involve anything from diverting run-off from adjacent lawns, to driving off excessive numbers of ducks whose manure is a nutrient-rich fertiliser.

Entwistle, Sonneman and Lewis (1997) is the most readily useable identification guide for most common species. See also *Chara* and *Nitella*.

Alisma. (Alismataceae) Water plantain (*A. plantago-aquatica*) forms extensive stands in some areas. Young leaves may be eaten by some waterbirds, seed rarely. The plants are handsome and shade tolerant, grow even on clay, and have considerable water treatment potential as they respond rapidly to high nutrient levels (see Colour Plate 15a). Seed has at least a three month dormancy period, and will germinate in shallow water but comes up more uniformly on waterlogged mud. It is reputed to lose viability within 12 months according to overseas sources, but is so copiously produced that it can be replaced each year without much effort. Larger plants that have formed several distinct crowns can be divided, but this is such a laborious task and the seed germinates so readily that this is rarely done.

Allocasuarina. (Casuarinaceae) See *Casuarina*.

Alternanthera. (Amaranthaceae) The indigenous species of this group are sprawling, shade-tolerant herbs that grow at the water's edge or in shallow waters, where they will float out into deeper areas. Often forming abundant and widespread stands, these are a food source for the young of some butterflies and moths, as well as larger animals including humans. Easily grown from seed or cuttings by the raised bog method, they will establish even on quite heavy clays.

Ampelopteris. (Thelypteridaceae) *A. prolifera* is a scrambling fern forming dense tangles along streams and in swampy, often shady places. It can be raised from spores, or plantlets which develop along the fronds.

Amphibolis. (Cymodoceaceae) Sea nymph (*A. antarctica*) is a common shallow water seagrass, and a significant habitat plant in relatively sheltered bays. It can be unreliably propagated by division, preferably established in pots of sandy soil with just a trace of fertiliser, so that the root mass can easily be anchored during planting out.

Amphibromus. (Poaceae) The diverse species of swamp wallaby-grasses all grow at the edges of fairly ephemeral wetlands where they may be flooded at times, and bone dry at others. Many act as annuals, especially in drought-prone climates. They are best grown from seed planted on waterlogged soil; this usually needs several months dry before it will germinate but otherwise doesn't present any problems.

Angiopteris. (Marattiaceae) Giant fern (*A. evecta*) is a huge, fleshy-rhizomed, primitive fern that has to grow in wet places as the immense fronds are kept erect by water pressure from below, unlike the fibre-reinforced fronds of most other ferns. This is a mostly tropical to subtropical species which has been over-harvested as a decorative plant, and is also endangered by wild pigs which relish its fleshy heart. Fresh spores can sometimes be raised on a sterilised sphagnum-and-peat medium mix, kept wet from below and with a clear cover above to keep humidity high. However, it is more reliably (and slowly) propagated from the ear-like bulges at the base of the fronds, removed and planted whole into a peaty mix. Even in warm conditions it may take over a year for young plants to develop by this method.

Aniseia. (Convolvulaceae) *A. martinicensis* is a climbing or sprawling tropical bindweed found along stream edges, and on floating mats of vegetation with its roots permanently wet. Easily grown from root divisions, the large seed will also germinate after nicking its hard coat, and planting into warm, moist soil.

Aphelia. (Centrolepidaceae) Tiny annuals found in flood-prone areas, where they self-seed even on clay, if not shaded by mats of larger plants.

Apium. (Apiaceae) Sea celery (*A. prostratum*) and the shorter-lived *A. annuum* are found around the fringes of coastal and saline wetlands, although sea celery will also grow in a more stunted form on sand dunes. Closely related to true celery and also edible though stronger-flavoured, they are easily grown from seed sown onto moist soil, or from runners when these are produced.

Aponogeton. (Aponogetonaceae) The native laceplants are mostly tropical to subtropical, with one species confined to south-western Western Australia. Some (especially the Queensland species *A. elongatus* and *A. bullosus*) have been collected on a considerable scale from the wild for aquaria, but all are now protected. The fine-grained tubers of some species were a favoured food among some Aboriginal peoples, but would be much more profitable if sold as aquarium plants than as comestibles!

All species I have tested apart from *A. bullosus* are no harder to grow from fresh seed than their exotic relatives, sowing seed in shallow, warm water, raising the water level gradually as they grow. Although most species are shade tolerant, intense light is important for strong growth and production of seed, and a dry, dormant period is needed once tubers are large enough to survive this. This is because they gradually lose vigour when permanently submerged. The Western Australian *A. hexatepalus* needs a particularly long dry spell of at least six months most years to thrive. Native laceplants generally do best in slightly hard, alkaline waters in cultivation.

Avicennia. (Verbenaceae) See general remarks under Mangroves at the beginning of this chapter.

Azolla. (Azollaceae) These floating ferns are attractive carpeting plants, but can smother the water's surface in smaller dams and pools. They are eaten by ducks and some livestock, and contain nitrogen-fixing blue-green bacteria so they have been used as fertiliser as well. Fairy ferns respond well to potassium fertilisation, propagating themselves at an alarming rate from the smallest piece.

Bacopa. (Scrophulariaceae) These are sprawling, small-leaved herbs of shallow water and wet soils, shade tolerant and may have potential in water treatment. Propagation is usually from cuttings, or seed if you have the patience to harvest it. *B. monniera* has medicinal uses and is also a food plant in South-East Asia.

Baloskion. (Restionaceae) These grass relatives form fairly upright tussocks which are sometimes a significant vegetation form in shallow, peaty wetlands. The widely grown and very decorative *B. tetraphyllum* will grow on clay, although it prefers soils with a reasonable amount of organic matter. Selected forms of this species are often propagated by division, but plantings for habitat purposes should be done from seed, sown while it is still relatively fresh onto wet soil with about 10% peat content.

Other species such as *B. australe* set much less seed, and are usually divided instead. Plantings done from division only should include both male and female plants mixed together, for later seed production and natural spread.

Bambusa. (Poaceae) *B. arnhemica* is a large bamboo which is often the dominant species along streams of the Northern Territory, and on higher ground in flood plains. Seed is not hard to germinate on moist soil in warm conditions, when it is available, and smaller seedlings are readily transplantable.

Banksia. (Proteaceae) No banksias are true wetland plants, but some such as swamp banksia (*B. robur*) are found on higher patches of ground in some wetlands, where their roots are unlikely to be flooded for more than a few days even in the wettest conditions. Propagation is usually from reasonably fresh seed, buried slightly in moist soil only as wet soils encourage fungal problems, and waterlogging will kill the germinating seed rapidly.

Barringtonia. (Barringtoniaceae) Freshwater mangrove (*B. acutangula*) is a tropical tree forming extensive stands in ephemeral tropical swamps that dry out for much of the year. It is sometimes grown as a red-flowered ornamental, and is easily grown from fresh seed sown immediately after collection. It is also called itchy-grub bush for the irritating effect of the hairs of Lymantrid caterpillars which feed on the leaves.

Batrachium. (Ranunculaceae) *B. trichophyllum* is a buttercup relative with finely divided underwater leaves. It is presently treated as a possible exotic in some Floras, although there is little evidence to base this opinion on, apart from its close relationship to very similar plants in the Northern Hemisphere. It is easily propagated by division or cuttings.

Baumea. (Cyperaceae) Twigrushes are a variable group, most of them growing in shallow, usually ephemeral waters, so they are very drought tolerant once established. *B. articulata* responds well to high nutrient levels, and has considerable potential for water treatment though it takes longer to establish than weedier species such as *Typha* and *Schoenoplectus tabernaemontani*. Propagation of most twigrushes by division of the rhizomes is straightforward, and the divisions will put out new roots while floating with anything from an 80% to a 95% strike rate after three months in warmer weather, or 6–7 months in colder times.

Seed gives more unpredictable results, which may vary dramatically between clones, populations, and seasons (as discussed in an earlier chapter), and isolated populations that are actually just a single, self-sterile clone may never develop viable seed at all. This is particularly true for *B. articulata* in southern Australia – the patchy populations furthest south in Victoria may be hundreds of kilometres apart, while seed from populations in coastal NSW which may only be separated by a 100 metres usually give much higher germination rates. Even seed known to be viable should be allowed to ripen fully after harvesting for six months to a year before planting.

Berula. (Apiaceae) *B. erecta* is a celery-like plant of shallow waters, possibly introduced, tolerating alkaline waters and shade, and with some water treatment potential. It is usually propagated by division as it multiplies readily, but seed germinates well if it is planted onto waterlogged soil in spring.

Blechnum. (Blechnaceae) Some water ferns form extensive colonies in and around wetlands, where they may be a significant habitat component, and these are mostly shade tolerant as well as moderately drought tolerant. Propagation from spores is not difficult by the methods described earlier, but needs to be started about two years before plants are required for planting out.

Blyxa. (Hydrocharitaceae) Grass-like, submerged annual plants of clear tropical waters, these grow fast after flooding. Introduce trays of actively growing seedlings which have been started ahead of the wet season into new wetlands that have already developed a layer of silt (however thin), and the abundant seed production will be enough to produce self-seeding stands for the next wet season. Several species are eaten in South-East Asia.

Bolboschoenus. (Cyperaceae) These clubrushes form extensive stands in shallow ephemeral waters, and are attractive as well as significant as habitat (see

Colour Plate 15b). The young tubers are good eating; older ones are woody with an unpleasant sulphurous aftertaste. Plants will grow in shade, on clay soils, have considerable water treatment potential, and are very drought tolerant once established. Although they are great colonisers even on fairly raw terrestrial soils, the corollary is that they are difficult to remove and replace with other, less competitive plants once established.

All three native *Bolboschoenus* are propagated from seed, which germinates readily after several months of dry storage, sowing onto waterlogged soils in warm conditions. Dormant tubers are easily transplanted and form larger plants quickly, but this labour-intensive propagation method is usually only used when plants are needed in a hurry.

Brachyscome. (Asteraceae) A group of small daisies, some species of which grow on soil hummocks just above the normally waterlogged zone in wetlands or at their fringes – they will also grow well on moist to wet clay. All species are easily grown from cuttings or divisions, while seed may need two or three months dormancy, and can be planted out on wet soil in autumn when it germinates most readily.

Brasenia. (Cabombaceae) Water shield (*B. schreberi*) grows best in fairly deep, warm waters and is winter dormant in southern Australia. The gelatinous young stems and leaves are regarded as a delicacy in China and Japan, and it has some water treatment potential although it won't grow on recently flooded terrestrial soils. Usually propagated by division or sometimes cuttings, water shield can also be grown from seed as for *Nymphaea* in the warmer parts of its range, but sets very few seeds as far south as Victoria.

Butomopsis. (Limnocharitaceae) *B. latifolia* is an annual tropical herb growing in seasonally flooded areas, flowering and setting seed as water levels fall. It will grow even on gravelly or heavy clay soils as long as these remain flooded long enough for it to complete the full growing cycle and set seed.

Caldesia. (Alismataceae) These broad-leaved herbs are tropical relatives of *Alisma plantago-aquatica* and can be grown and treated in much the same way, although propagation is from seed only as they are usually annuals.

Callistemon. (Myrtaceae) Many bottlebrushes grow along streams or on higher ground in swampy places, where they may be flooded for short periods of time. Closely related to *Melaleuca*, they are best raised from seed for wetland plantings, but ornamental cultivars are usually propagated from hardwood cuttings.

Callitriche. (Callitrichaceae) These are small-leaved creepers of shallow waters and wet soils, most native species are becoming less common as their habitats are increasingly taken over by introduced relatives *C. stagnalis* and *C. hamulata*. They are easily propagated by division or stem cuttings; seed is difficult to collect in any quantity.

Calystegia. (Convolvulaceae) *C. sepia* is found twining through reed and rush stems around wetland fringes, often in areas that flood occasionally but not for long (see Colour Plate 16a). The seed is large and easily gathered once the plants have died away in winter, but has a hard coat which should be nicked before planting, or worn thin by tumbling with fine gravel for up to an hour. Dry seed heated to around 60–70°C for half an hour is also reputed to germinate well. Stem cuttings and divisions are a quicker option if only a few plants are needed in a hurry.

The dense growth and scrambling habit allow *Calystegia* to compete very effectively with even the tallest reeds and sedges, so it should be used with care in high-nutrient situations where it may smother all other vegetation, as the mats of wiry, twining stems are impenetrable to all but the smallest animals.

Carex. (Cyperaceae) All wetland species of these diverse, grassy sedges can form extensive stands, and many of them are significant shelter and seed-producing plants. Nearly all species can be propagated from seed easily by planting on wet to waterlogged soils, and will germinate within a few months of harvest. One exception is *C. gaudichaudiana* which doesn't seem to set viable seed often. Fortunately, this running species can be divided readily, as can the clump-forming tassel sedge *C. fascicularis* (see Colour Plate 16b). By contrast, deeper-rooted species such as *C. appressa* resent division and recover from it very slowly.

Carpha. (Cyperaceae) This plant is similar in habit and habitat to *Oreobolus*, and propagated in the same ways.

Casuarina. (Casuarinaceae) Swamp she-oak (*C. glauca*) is a medium sized tree usually found near water including around lakes, tolerating wet conditions at all times, but not permanent waterlogging. This species and some of the related but generally smaller *Allocasuarina* species found in seasonally wet heathlands are all readily propagated from seed sown onto moist to wet soil.

Centella. (Apiaceae) *C. cordifolia* and the similar *C. asiatica* are creeping plants of wetland fringes with kidney-shaped leaves. The latter species has been used in Asia as a leaf vegetable and a broad-spectrum medicinal plant under such names as Gotu Kola, and used in Australia for specific complaints such as arthritis. It is easily propagated by division; the seed is time consuming to harvest but germinates readily on moist soil.

Centipeda. (Asteraceae) These are small, short-lived, sprawling or upright daisies found at the fringes of wetlands, flowering as water levels fall. Some species are powerfully and pleasantly aromatic, and have been used as a treatment for colds and sore eyes. Cuttings from young plants will take root easily, and seed germinates freely on wet soils.

Centrolepis. (Centrolepidaceae) These are tiny, tussock-forming plants growing on wet to waterlogged soils, and tolerating prolonged flooding. They are easily propagated by division, after which they will self-seed freely especially on clays where there isn't too much competition for living space. In drier sites where there is only a short growing season, these plants will grow as annuals.

Cephalotus. (Cephalotaceae) Albany pitcher plant is a small, carnivorous plant from south-western Western Australia, found growing in low clusters in peaty, swampy and generally sandy areas. The curious, bristly pitchers trap and break down insects as a source of nitrogen, phosphorus and potassium that are in short supply in peaty soils. It is not an easy plant to grow, let alone transplant back into natural conditions, although some collectors of carnivorous plants have had some success with it as a cultivated ornamental. A painfully slow-growing species, it needs moist to wet conditions in full sun or with some shade from the west in drier climates, and will only tolerate waterlogging for relatively short periods of time. Freshly collected seed should be chilled for two or three months before sowing onto a mix of finely sieved peat and sand, and may take months to germinate.

Ceratophyllum. (Ceratophyllaceae) Hornwort (*C. demersum*) is a floating plant with whorled leaves, superficially similar to the submerged leaves of *Myriophyllum*. It can form dense tangles, especially in cool, clear, moving waters and in the shade of taller reeds and sedges, where it provides shelter and spawning sites for a wide variety of underwater animals. Hornwort responds well to fertiliser so there is some potential for use in water treatment, but in excessively nutrient-rich waters it will be smothered by competing algae. It grows best in slightly alkaline waters, and is easily propagated from any growing tip floated in water as the plants do not put out roots.

Ceratopteris. (Parkeriaceae) These are soft ferns that may take root or float. They may grow under water or with foliage above the surface. These ferns are eaten by a wide variety of waterbirds, with one species at least used as food by humans, and they are also used as shade-tolerant aquarium plants. Propagation is usually from the plantlets which form along the edges of mature leaves, but spores sown on warm mud will also grow readily in the absence of competing species.

Chaetanthus. (Restionaceae) Western Australian cordrushes from seasonally wet heathlands, these are fairly readily grown from seed sown onto a sandy, peaty soil mix with a small amount of blood-and-bone mixed in as fertiliser.

Chara. (Characeae) Stoneworts are curious, branching species of algae that are frequently mistaken for flowering plants; their distinctive smell has generated another common name – muskgrass. The dense thickets of growth are home to a wide range of smaller invertebrates, and make a good spawning site for some smaller fishes. All species have potential in water treatment although a few may die off suddenly in a mass, which is less than useful for this purpose. Others may actively help to clear fine clay particles from water, perhaps by concentrating lime which bonds tiny clay particles into larger ones that settle more readily. Propagation is by division; pieces may be teased apart and then weighed down with a stone or clod of clay. Most are tolerant of lime (many prefer calcium-rich water), moderate levels of salinity and some shade.

Chordifex. (Restionaceae) Western Australian cordrushes, most species of which grow in fairly dry situations but some in much wetter habitats. They are nearly all easily raised from seed sown as described under *Chaetanthus*.

Chorizandra. (Cyperaceae) These are moderately tall sedges from wet to seasonally flooded areas, sometimes a dominant vegetation form over large areas. They are not difficult to grow on wet soil from seed. *C. enodis* is widely grown as an ornamental, but the most decorative forms are usually propagated by division for this purpose. Most species will grow on clay, and may have water treatment potential, although they are not as fast growing as the most nutrient-responsive sedges. They are very drought tolerant once established.

Christella. (Thelypteridaceae) Running ferns forming dense stands in ideal situations along the banks of streams and on swampy ground, and fairly easily propagated from spores while these are still fresh. Plants raised from spores are slow to form sizeable plants, so propagation is usually by division of the runners.

Cladium. (Cyperaceae) *C. procerum* is a giant sedge found in seasonally flooded areas and on wet soils, often near the coast so it tolerates saline conditions at times. It is uncommon over much of its range but is a significant shelter species when it forms extensive stands. It is easily propagated on waterlogged soil if seed is available, but many stands don't seem to form seed and reproduce by proliferations instead. These may be just a single, self-sterile clone which has spread widely in this way. As the proliferations are large, they can usually be separated into a number of plants.

Colocasia. (Araceae) Selected forms of taro (*C. esculenta*) are an important food in many tropical countries, and may have been the first cultivated crop anywhere. Some botanists believe that taro may have been introduced to Australia, but this seems unlikely on two counts. First, the earliest definite centre of cultivation was in New Guinea, which suggests that it may have been indigenous there. As New Guinea was linked to Australia by a land bridge only a few millennia ago, there is no reason to think that taro could not have spread naturally to northern areas of this country, as have many other plants.

The second reason is more compelling. Wild, native taros grow differently from the selected edible forms (they are exactly like wild forms found elsewhere), and most of them cannot be made palatable by any known treatment! It is extremely unlikely that anyone would have introduced these deliberately. Wild taros are readily grown from seed planted in waterlogged soil and by division of the runners. By contrast, few cultivated taros produce seed and only infrequently at that, and these all produce suckers around a central corm rather than runners.

Commelina. (Commelinaceae) Several native species of *Commelina*, and also their close relatives in *Murdannia* and *Cyanotis*, grow as short-lived annuals around the fringes of tropical wetlands, though there are also some longer-lived species in cooler climates further south where the contrast between wet and dry seasons is not so great. All are easily raised from fresh seed sown onto moist soils, and some will also establish quickly from cuttings during their most active growing season.

Cotula. (Asteraceae) These are creeping daisies found from the water's edge to moderately deep waters, depending on species. Waterbutton (*C. coronipifolia*) is presently treated as a possible exotic in some contemporary Floras but there is good evidence that it has been in Australia for many thousands of years, as has been discussed in Chapter 4. There are also several smaller native species but only waterbutton is a significant habitat species, particularly in slightly saline wetlands. All species are readily propagated by seed sown onto wet soils, by division, or for waterbutton from elongated, submerged cuttings.

Craspedia. (Asteraceae) These are upright daisies with globular flowers, found around the fringes of wetlands where they may be flooded in the wetter months. The showy flowering plants can form extensive stands in shallow, seasonally flooded wetlands and are often associated with grasses or smaller sedges. Such wetlands are often rich in invertebrates, not necessarily just aquatic or wetland species. All species are readily propagated by seed kept moist to wet, but not waterlogged, and by division or cuttings.

Crassula. (Crassulaceae) Swamp stonecrop (*C. helmsii*) is a creeping plant of shallow waters and very wet soils. It forms a dense groundcover which will inhibit the germination of smaller seeds of unwanted species such as *Typha*, and is fairly shade tolerant. Usually propagated by division or cuttings, this is our most successful wetland weed export, and is still a problem even in the cold climates of southern England.

Crinum. (Amaryllidaceae) Several species of these showy, trumpet-flowered, lily bulb-like plants (see Colour Plate 17a) grow around the margins of streams and lakes, or on floodplains, but never in places where they are likely to be flooded for more than a day or two at a time. All native species are easily raised from seed, buried shallowly in nutrient-rich, moist but well drained soil at temperatures above 23°C.

Cyanotis. (Commelinaceae) The propagation and ecology of *C. axillaris* is similar to that for *Commelina*.

Cyclosorus. (Thelypteridaceae) These coarse-looking running ferns form extensive stands in wet places, and tolerating full sun as long as their soil doesn't dry out. *C. interruptus* is usually propagated by division, but is not difficult to grow from fresh spores sown as described in the previous chapter.

Cyperus. (Cyperaceae) This is a diverse group of sedges, found from shallow seasonal waters to much drier environments, and often forming extensive stands that are an important shelter habitat for birds and many other animals. The larger species are often adapted to seasonal flooding, and may stand in water for much of the year (see Colour Plate 17b). These have potential in water treatment as they respond well to high nutrient levels; by contrast, the native annual *C. difformis* is regarded as a serious weed of rice crops.

Most leafrushes are readily propagated by division, although they can be slow to recover from root loss. Nearly all are more readily propagated from seed, with the exception of *C. lucidus* which is host to a fungus that destroys much of the immature seed. The seed harvest in this species can be improved to some extent by growing stock plants from several local sources together, in a group in a site which dries out by later spring, and by spraying with a dilute Bordeaux (copper sulphate) mix after rain. Seed of *Cyperus* species will usually germinate fairly well even after two years of dry storage, but viability starts to fall off rapidly after this stage in many species.

Cytogonidium. (Restionaceae) *C. leptocarpoides* grows in seasonally flooded Western Australian heathlands, and regenerates generously from seed after fire or disturbance of the soils where it grows. Sow as for *Chaetanthus*.

Damasonium. (Alismataceae) This plant is like a miniature *Alisma*, growing in shallow but ephemeral waters and flowering as these recede. It is an annual plant that grows best in the absence of dense competing and shading vegetation; propagation is by seed only, sown into shallow, clear waters.

Diplachne. (Poaceae) See *Leptochloa*.

Distichlis. (Poaceae) Australian saltgrass (*D. distichophylla*) is a creeping or running grass on saline soils, but will also grow in freshwater situations in the absence of competing plants (see Colour Plate 18a). It is not difficult to propagate from runners, or seed sown onto wet soil if you have the patience to collect any quantity.

Drosera. (Droseraceae) Forked sundew (*D. binata*) grows on waterlogged soils and at the fringes of wetlands; more northern populations are sometimes multiple-branched, while in the south a single fork is more usual. Propagation is easy from seed, division, and leaf or root cuttings, all of which should be planted into or on wet soil.

Duckweeds. (Lemnaceae) The various species of *Lemna*, *Spirodela*, *Landoltia* and *Wolffia* are all small, floating plants that can cover the surface of small water bodies thickly, but are unlikely to choke the surface as *Azolla* can over much larger areas. All duckweeds are eaten by diverse waterbirds and some fishes, and provide protective cover for some frogs.

All species multiply themselves readily from even a single piece, and are moderately shade tolerant. In South-East Asia a species of *Wolffia* closely related to the native *W. australiana* is one of the most spectacularly productive, high-protein and carbohydrate plants cultured in ponds, producing a saleable *dry* weight of around 10 tonnes per hectare over the nine-month harvest period – see Romanowski 2007.

Echinochloa. (Poaceae) Swamp barnyard grass (*E. telmatophila*) is a tall, annual grass found at the fringes of wetlands, and grows best with prolonged flooding. It is propagated by seed, which should be stored dry for several months before planting.

Eclipta. (Asteraceae) *E. prostrata* is a small-flowered, annual daisy that is most frequently seen as a weed on seasonally wet, disturbed ground, and grows readily from seed. It has been harvested (though not cultivated) as a vegetable in South-East Asia, and used as a medicinal tea.

Elatine. (Elatinaceae) *E. gratioloides* is a creeping plant of shallow waters and wet soils, tolerating shade and growing in clear, running water. It can form dense mats, and is usually annual although it may be a short-lived perennial in permanent waters. Propagation is from seed sown on waterlogged soil, or by division once it is in active growth.

Eleocharis. (Cyperaceae) These are upright to sprawling sedges growing from quite deep waters to ephemeral shallows. Most *Eleocharis* species form extensive stands, and are significant habitat for nesting birds, as well as for reed-dwelling species and for smaller animals (see Colour Plate 18b). One native species, Chinese waterchestnut (*E. dulcis*), produces high-quality edible tubers, but the commercial forms of this were selected in China and are larger-tubered than native ones.

The rhizomes of tall spikerush (*E. sphacelata*) are reputed to have been eaten by one dubious source, but are poor quality and were only likely to have been a famine food, if that. This particularly vigorous species is still often planted in created wetlands, but seems to have an allelopathic effect on many other plants, and as it will grow in water over 3 m deep, can soon become the sole occupant of even large dams and wetlands. Reports from the Northern Hemisphere also record spikerushes as allelopaths.

Many spikerushes grow well with high nutrient levels, and have moderate water treatment potential. Propagation is easy by division, or from seed sown on a waterlogged bog, and some species are annuals that grow at the fringes of more extensive wetlands.

Empodisma. (Restionaceae) Twining roperushes are upright, grassy plants that may scramble through other vegetation around wetlands, usually in seasonally wet soils, and they also tolerate prolonged waterlogging. They will grow in well-shaded situations (though seed may not be produced if light levels are too low) and are moderately drought tolerant once established. Fresh seed sown onto wet soil will germinate fairly readily, even on clay.

Enydra. (Asteraceae) Buffalo spinach (*E. fluctuans*) is a shade tolerant, running herb of shallow waters through South-East Asia as far south as northern New South Wales. In Asia it is a weed in rice-fields. It also cultivated on a small scale around fishponds and slow streams as a green vegetable. Propagation is easy from stem cuttings, and seed germinates readily on waterlogged soils.

Epilobium. (Onagraceae) A number of smaller species of annual willowherbs are found around the moist fringes of wetlands, where they are frequently weedy and may outcompete even many introduced species. Only showy willowherb (*E. pallidiflorum*) is habitually aquatic, perennial, and reliably propagated from cuttings. This large-flowered species is usually found scrambling up through taller reeds and rushes in shallow to quite deep waters, and is fairly shade tolerant. All willowherbs are also easily propagated by their wind-dispersed seed on moist to wet soils.

Eragrostis. (Poaceae) Canegrasses are inland species found in clay depressions that only fill during periods of heavy rain, with water evaporating within months or even just weeks, although *E. infecunda* will grow permanently inundated as well. All species are very drought tolerant when established, will grow on clays, tolerate moderate degrees of salinity, and are fairly tolerant of wind action. They are easily grown from seed which should be stored dry for at least six months for good germination. Division is not hard, but plants are slow to re-establish roots.

Eriocaulon. (Eriocaulaceae) *E. setaceum* is a feathery plant of seasonal tropical waters, with curious button-like flowerheads (see Colour Plate 19a). It is often an annual, and is readily propagated from seed (which will germinate well even after seven years stored dry) sown into shallow water. The smaller, tuft-forming and more upright species in this genus are widespread across Australia at the fringes of wetlands, where they may be flooded for months in the wet season. Propagation for these is from seed sown onto wet to waterlogged soils.

Eryngium. (Apiaceae) Tanglefoot (*E. vesiculosum*) is a variable, spiny-leaved, drought tolerant herb of wetland fringes which thrives even on clay (see Colour Plate 19b). *E. ovinum* is also found on heavy clay soils in seasonally wet depressions, and both are easily propagated from seed on wet soil, by division and by root cuttings.

Eucalyptus. (Myrtaceae) Several eucalypts are found in seasonally flooded areas, the best known of these being river redgum (*E. camaldulensis*) and coolabah (*E. microtheca*). These widespread and common species are a threatened riverine habitat in places, though still reasonably common and healthy over much of their range despite continued logging. They will gradually weaken and eventually die if regularly kept flooded for longer than they are adapted to. Propagation is from seed; some relatively salt-tolerant strains of river redgum are available.

Ficinia. (Cyperaceae) Seed of the upright knobby clubrush (*F. nodosa*, previously *Isolepis nodosa*) is easily collected in quantity and germinates readily on moist to wet soils. This is probably why it is sometimes included in wetland plantings even though it is not a true wetland species, preferring the drier fringes, and growing abundantly on sand dunes in higher rainfall areas.

Fimbristylis. (Cyperaceae) These are small, mostly annual sedges growing around the fringes of tropical wetlands. They are readily established from seed sown onto wet soil but do not persist once shaded by competing vegetation.

Frankenia. (Frankeniaceae) Sea heaths are low, sprawling shrubs of coastal saltmarsh, growing on higher, seasonally waterlogged ground; some species are also found inland. All are easy to grow from cuttings or layered stems.

Fuirena. (Cyperaceae) The semi-aquatic *F. umbellata* looks like a curious five-sided grass rather than the sedge it actually is, and grows even in moving water for months at a time (see Colour Plate 20a). Seed is not produced in large amounts, but germinates reliably on warm, wet soil, and plants can be divided.

Gahnia. (Cyperaceae) Gahnia grow as medium to very large tussocks, often forming extensive stands that provide shelter for a variety of animals, and are also eaten by a variety of insects including caterpillars. Few of the species will survive division, and any survivors take their time recovering from the associated root loss. Propagation from seed has its complications, although all species should be sown moist to wet rather than waterlogged. Seed of some such as *G. melanocarpa* and *G. filum* will germinate almost as readily as lawn seed at times. The harder-shelled, red seeds of *G. clarkei* and *G. sieberiana* should be sown into warm, moist soils after a 12–18 month dormant period, while *G. radula* rarely sets seed and is almost impossible to transplant (see Colour Plate 20b).

Gleichenia. (Gleicheniaceae) Coral ferns grow with their roots in very wet soils and their tops in bright light, some scrambling up taller shrubs to reach sunlight (see Colour Plate 21a). The most aquatic species is pouched coral fern (*G. dicarpa*), which will tolerate running water, but all are indicators of permanently moist to wet ground, where their extensive tangles provide shelter for smaller animals including mammals such as *Antechinus*. They will tolerate prolonged flooding, clay soils, and some shading, and are easily grown from spores though slow-growing initially. Young plants can be transplanted with care, but it is almost impossible to divide or transplant older plants successfully.

Glossostigma. (Scrophulariaceae) These are tiny-leaved creepers of ephemeral waters, flowering as the water levels fall; all are easily propagated from fresh seed sown onto mud, or by division. *G. elatinoides* is used as an aquarium plant in Japan, and will probably be more widely used as an ornamental carpeting plant as it becomes better known elsewhere (see Colour Plate 21b).

Glyceria. (Poaceae) Austral sweetgrass (*G. australis*) is a significant habitat plant, forming extensive stands in seasonal waters up to half a metre deep, and tolerating permanent flooding. In more ephemeral wetlands it may grow as an annual, returning in the next wet season from seed. The seed is eaten by many waterbirds, and plants survive even quite heavy grazing by livestock. These plants will grow on clay, respond well to high nutrient levels and so they may have potential in water treatment. They are easily propagated by division and from seed sown on wet soil after several months' storage.

Goodenia. (Goodeniaceae) Swamp goodenia (*G. humilis*) is a small creeping plant found around the fringes of wetlands. It is usually propagated by division, but is not difficult from seed sown wet (but not waterlogged) if you have the patience to harvest it.

Gratiola. (Scrophulariaceae) These are sprawling or upright creepers of seasonally wet places, tolerating permanent shallow flooding as well. *G. peruviana* is a perennial that will grow on clay, in quite dense shade and possibly has water treatment potential. It is easily raised from cuttings or divisions, while annual species such as *G. pubescens* must be grown from seed.

Gunnera. (Gunneraceae) This plant is found only in Tasmania. *G. cordifolia* grows at the edges of permanently wet places, is often associated with *Sphagnum*, and is tolerant of waterlogging. A densely carpeting species which multiplies rapidly, it is easily propagated by division. Fresh seed will also germinate readily on wet, peaty soil.

Gymnoschoenus. (Cyperaceae) Buttongrass (*G. sphaerocephalus*) forms extensive stands along the fringes of waterways and across damper valleys where it may be flooded by heavy rains. In Tasmania, buttongrass plains form extensive habitat areas, kept clear of encroaching teatree which would shade them out by fairly frequent fires. Propagation is usually by division which is slow and not always reliable, but seed is rarely found especially on the mainland. At one stage this was a fashionable name among gardeners, although most plants sold under this name were actually *Xyris* or sometimes *Baloskion australe*.

Halophila. (Hydrocharitaceae) These are unusual seagrasses with broad, rather rounded leaves, growing from very shallow water to depths of many metres. Rhizome sections take root readily in clear waters but are brittle and easily damaged, so care is required in handling.

Haloragis. (Haloragaceae) Swamp raspwort (*H. brownii*) is a sprawling herb of wet places that may flood for long periods of time, and it tolerates moderate salinity as well as some shade. It is readily propagated from cuttings or divisions. As with the closely related *Myriophyllum*, seed is often freely produced though hard to collect in any quantity, and should be sown onto waterlogged soil. A few smaller, short-lived species grow at the fringes of wetlands and are readily propagated by cuttings, division, or seed sown onto wet soil.

Halosarcia. (Chenopodiaceae) Glassworts grow in coastal saltmarshes prone to tidal flooding, some also on low-lying saltpans inland that only fill after heavy rains. They can form extensive stands which are excellent shelter for secretive birds such as crakes and rails. Seed may be slow to germinate and should be kept moist rather than wet to minimise fungal problems, and cuttings will strike fairly readily.

Hanguana. (Hanguanaceae) *H. malayana* is a tall and upright, strap-leaved herb, probably related to the ginger family but a true aquatic of shallow, permanent waters near northern coasts. It is usually propagated by division, but the large seed will germinate fairly readily if pushed into wet, nutrient-rich soil.

Helmholtzia. (Philydraceae) Stream lily (*H. glaberrima*) is a strap-leaved tussock of stream banks in shaded gullies from northern NSW into Queensland. Often grown for its tall, creamy-pink flower columns, it is raised from fresh seed sown into moist soil in warm, shaded conditions, or by division of the crowns for selected ornamental forms.

Hemarthria. (Poaceae) *H. uncinata* is a short, densely growing grass found in wet places, tolerating waterlogging for some time, moderate degrees of salinity, and some shade. It is easily propagated by division or seed, although this is time consuming to collect.

Heterozostera. (Zosteraceae) This is a seagrass closely related to *Zostera*, and probably propagated in the same way.

Hydrilla. (Hydrocharitaceae) *Hydrilla* is a submerged plant which can be invasive in warm, clear but nutrient-rich situations. It is readily eaten (and kept controlled) by waterbirds, particularly ducks and swans, and also easily propagated from cuttings, or from turions and tubers formed when the plant begins to die down towards winter.

Hydrocharis. (Hydrocharitaceae) Frogbit (*H. dubia*) is a creeper of shallow waters, floating out over deeper areas. It can cover extensive areas and is propagated mainly by division, but is probably not difficult to grow from seed sown in warm, shallow water.

Hydrocotyle. (Apiaceae) These are creeping plants with rounded leaves, growing from wet soils to shallow waters depending on species. All are easily propagated from seed or by division; the semi-aquatic species will germinate on waterlogged soil, but the others should be kept drier.

Hygrochloa. (Poaceae) These short-lived, often annual grasses from seasonally flooded places are easily grown from seed sown onto wet soil after a long, dry dormancy.

Hygrophila. (Acanthaceae) Tropical herbs of seasonally flooded areas, many of these are shade tolerant and well known as aquarium plants. They are easily grown from cuttings; the native *H. angustifolia* also produces considerable numbers of seeds that germinate readily on wet soils, and even on clay.

Ipomoea. (Convolvulaceae) This genus includes two native, creeping plants of ephemeral, tropical waters. Both can be propagated as for *Calystegia*, but can also be grown from stem cuttings. In Asia, water spinach (*I. aquatica*) is a popular and highly productive vegetable. However, the Australian forms of this species are woodier-stemmed, and the only part of the plant recorded as having been eaten by Aboriginal peoples are the tubers.

Isachne. (Poaceae) Swamp millet (*I. globosa*) is a shortish, attractive grass growing in seasonally wet shallows, and also more permanent waters. Seed is abundantly produced and is eaten by some waterbirds, despite its bitterness. It is easily germinated in warm conditions after a dry storage period, sown onto waterlogged soils. Individual plantlets growing along the runners can be separated and divided with a bit of work.

Isoetes. (Isoetaceae) These are curious fern-relatives forming grassy tufts, some in shallow ephemeral pools as annuals, while perennial species spread to form lawns in shallow water, from Tasmania to the tropics. Little is known of their propagation from spores, but the perennial species are easily propagated by separating their growing crowns.

Isolepis. (Cyperaceae) There are numerous species of small, tufted sedges in this genus, mostly found around the fringes of wetlands, and sometimes in shallow waters as well (see Colour Plate 22a). The smaller species are often annual and are mostly shade tolerant. They are readily divided while still young or they can be grown from seed sown on wet to waterlogged soil. *I. fluitans* is a perennial, shallow to quite deep water species that forms extensive floating carpets taking root on mud as water levels fall. The stranded carpets of this species are easily divided. See also *Ficinia*.

Isotoma. (Campanulaceae) Swamp isotome (*I. fluviatilis*) is a tiny-leaved creeper of shallow waters and wet soils, often grown as an ornamental as it flowers prolifically. It is usually propagated by division as seed is not easily gathered in any quantity.

Juncus. (Juncaceae) The rushes are a large and diverse group varying from small annuals to tall, upright tussocks in habit. As many species are reasonably immune to livestock damage, they have probably become considerably more abundant since European settlement, surviving even on heavily grazed paddocks. Using present day abundance of such weedy plants as a guide to reconstruction of natural wetlands is not recommended – use most *Juncus* species sparingly or not at all, as they will often invade new wetlands of their own accord. Some including *J. pallidus* are as frequently found in drier habitats as in wetlands, while others such as *J. procerus* are an indicator which are regularly flooded for months at a time.

All *Juncus* species are easily grown from their copiously produced seed, which is reputed to have short viability. Nearly all species germinate at close to 100% even after two years of dry cold storage, when sown on moist to wet soils. The most aquatic species, *J. ingens*, has male and female flowers on separate plants and is the one exception which doesn't reliably set seed, as the sexes sometimes flower at different times. Seed of the estuarine species *J. kraussii* is produced much later than that of most other tussock-forming types, and can be harvested from early winter onwards. Despite its extreme tolerance to salt water, the seed of this species does not need salt to germinate or grow.

Lachnagrostis. (Poaceae) Common blown grass (*L. avenacea*) is one of the fringe-dwellers that should possibly have been excluded from these lists. However, it is so common and abundant on heavy, wet soils around the fringes of wetlands in southern Australia that it is likely to be a significant habitat plant in places. It often grows as an annual, and is easily raised from the prolifically produced seed.

Landoltia. (Lemnaceae) See duckweeds.

Leersia. (Poaceae) *L. hexandra* is a tall, tropical grass that can be invasive in ricefields, but is also an important habitat plant in seasonally flooded areas, and in deeper waters it will form floating mats. It is easily propagated from divisions or by seed sown onto wet soils.

Lemna. (Lemnaceae) See duckweeds.

Lepidosperma. (Cyperaceae) This sedge genus is mainly terrestrial, but pithy swordsedge (*L. longitudinale*) and its relatives grow in seasonally flooded areas which may remain dry for years at a time, forming dense and extensive stands which tolerate prolonged inundation (see Colour Plate 22b). It resents division, and is slow to re-establish. Viable seed does not seem to be produced reliably perhaps because of self-pollination problems, or the harshness and unreliable conditions of the environments in which these plants are usually found.

Lepilaena. (Zannichelliaceae) These plants forming tangled underwater mats are closely related to *Zannichellia* and can be propagated in a similar way. The two genera are difficult to tell apart when not fruiting.

Lepironia. (Cyperaceae) *L. articulata* is a giant, tussock-forming sedge forming extensive stands in both permanent and ephemeral wetlands. The roasted rhizomes can be eaten, although harvesting them is labour intensive and is not recommended for propagation purposes. This is an important fibre-plant which has been used to make everything from sails to tough packing mats. Seed is sparsely produced relative to the size of the plants, but germinates readily when sown on waterlogged soil. Beware of the very sharp tip of the leaf when harvesting as this is around human eye-level and can cause serious injuries.

Leptocarpus. (Restionaceae) This used to be a large and complex genus of many species, now it is reduced to just three species of cordrush all found in sandy heathlands that are flooded from weeks to months at a time. *L. tenax* is the most widespread in both eastern and Western Australia, and is often found in areas where its roots may be submerged for months; it is also fairly salt tolerant. It does not produce seed reliably and is usually propagated by division; plantings done from division alone should include both sexes for seed production later. The other two species seed freely and are not difficult to grow by the raised bog method.

Leptochloa. (Poaceae) Umbrella canegrass (*L. digitata*) is an upright grass of ephemeral wetlands in inland areas. Similar in general appearance and preferred habitat to *Eragrostis australasica*, it is raised from seed planted as for that species. This genus also includes several attractive annual or short-lived perennial grasses of shallow waters and wet soils, flowering most of the year and spreading readily by seed. At least one of these is regarded as a weed in rice crops in southern Australia, but they are also potentially valuable grazing and a useful seed source for many birds.

Leptospermum. (Myrtaceae) Some of these are shrubs of permanently moist to wet places, and can tolerate prolonged periods of flooding although this is not their preferred habitat. The timber is hard and quite durable, and was used by Kooris for many-purpose hard-wearing tools. Early European settlers used the timber to make jetties, and for rudimentary buildings. Propagation is easy from seed sown on moist soil.

Lepyrodia. (Restionaceae) This is a large and widespread genus of cordrushes, many of which are found in seasonally flooded heathlands. Of these, around half produce seed in reasonable quantity, and this is easily germinated on wet, sandy, peaty soils as for *Chaetanthus*. The others tend to re-sprout after damage (especially after fires), but all species are slow and difficult to establish by division and seed is not often formed.

Lilaeopsis. (Apiaceae) These small, sprawling and rather tangled plants are superficially like some sedges or rushes in appearance. There may be several species lumped under the one name *L. polyantha* at present, so use of local provenances is essential in planting. All are readily propagated by division, or from seed sown onto wet soil, though this is hard to collect in any quantity.

Limnophila. (Scrophulariaceae) Tropical herbs of deep to shallow, often ephemeral waters, these are usually propagated from cuttings, which take root readily. Some native species are used as aquarium plants, and several including *L. aromatica* as a vegetable or seasoning in South-East Asia.

Limosella. (Scrophulariaceae) Mudmats are small, creeping plants of shallow ephemeral waters, flowering as water levels fall. They are easily propagated by division, or from the freely produced seed. *L. australis* appears to shed its seed explosively, and will spread itself rapidly by this method.

Liverworts. See *Marchantia*, *Riccia* and *Ricciocarpus*.

Livistona. (Arecaceae) *L. benthamii* is a tall palm found near watercourses, where it is often flooded during the wet season. It is not difficult to grow from fresh seed sown onto warm, moist soil, germinating after several months.

Lobelia. (Campanulaceae) Lobelias are low-growing herbs found around the fringes of wetlands. Some such as *L. pratioides* tolerate prolonged flooding; others such as *L. alata* are generally found on tussocks and other raised surfaces above the average maximum watertable. All are easily raised from seed on wet soil, by cuttings, and by division. They will grow on clay, and in the shade of other plants. The plants formerly known as *Pratia* are now all part of this genus.

Ludwigia. (Onagraceae) These are creeping plants of shallow water, or herbs found in shallow water and around the water's edge. *L. peploides* and its tropical relatives will trail long floating stems out from the shoreline. All are tolerant of shade although they may not flower if kept too dark, and they respond well to high nutrient levels so have potential for water treatment. They are easily grown from seed or cuttings. There is some doubt as to whether *L. peploides* is indigenous; in any case its weedy growth in disturbed soils makes it an undesirable candidate for most newly planted wetlands.

Lycopus. (Lamiaceae) Austral horehound (*L. australis*) is a tall herb that usually grows on the drier fringes of wetlands, but will also tolerate prolonged flooding. It can form dense thickets and is useful as shelter for smaller animals. Propagation is by the abundantly produced seed sown onto moist to wet soil, and by division.

Lythrum. (Lythraceae) Some botanists have suggested that there are no native species in this genus, but records of pollen in lake-bed core samples are now known to go back at least 2000 years. Purple loosestrife (*L. salicaria*) is a tall herb with showy flower columns, while *L. hyssopifolia* is a sprawling annual with some salt tolerance. Both grow in shallow water and on wet soils, and are readily propagated by seed sown on wet to waterlogged soil. Purple loosestrife cuttings strike readily. It is interesting that this species is regarded as a serious wetland weed in North America, while native forms are far from invasive even under ideal conditions, suggesting a long period of adaptation to conditions in south-eastern Australia.

Maidenia. (Hydrocharitaceae) These fine-leaved, submerged annuals are from tropical areas, propagated by seed sown in shallow to moderately deep but clear waters – see also *Vallisneria*.

Malva. (Malvaceae) Australian hollyhock (*M. preissiana*, synonym *M. australiana*) is a tall herb of saltmarsh fringes (see Colour Plate 23a). It grows in areas that may be waterlogged for weeks at a time and is easily raised from seed.

Marchantia. (Marchantiaceae) Creeping liverworts look remarkably like melted tongues of green wax, and have curious umbrella-like reproductive organs held above the foliage in summer. They are usually unnoticed even though they sometimes cover significant areas of ground around streams, grassy wetlands, and in coastal soaks. All species reproduce readily from even a tiny piece, and they often appear spontaneously in well-watered areas of nurseries.

Marsilea. (Marsileaceae) Nardoos are running ferns with clover-like leaves, found from shallow, ephemeral waters to deeper, more permanent ones. All are very drought tolerant once established, will grow on clay, and tolerate moderate shading. They have some potential in water treatment, and the spore cases of several species (formed as water levels fall) are edible, usually ground into a kind of flour. Propagation is by division, but the dry spore cases split after wetting and the spores start to grow rapidly, so propagation by this method may be viable.

Maundia. (Juncaginaceae) This is a fleshy, almost iris-leaved plant of shallow, ephemeral waters, attractive but increasingly uncommon and worthy of special conservation efforts in created and restored wetlands. It is not easy to propagate by division; fresh seed is best sown onto waterlogged soil or under shallow, clear, warm water.

Mazus. (Scrophulariaceae) *M. pumilio* is a tiny-leaved creeper of wetland fringes, forming carpets among taller plants. It is widely grown as an ornamental for its small but showy flowers, and is readily propagated by division or from fresh seed (see Colour Plate 23b).

Meeboldina. (Restionaceae) Most of these cordrushes grow in seasonally flooded sandy heathlands and along streams, re-sprouting from the base after fire (see Colour Plate 24a). Some set seed freely and are readily raised on wet soils as described for *Chaetanthus*, and the seed of one species at least seems to be stimulated into germination by smoke treatment. The majority are usually propagated by division which is not difficult as they are fairly robust plants, but both male and female plants need to be included in any replanting done this way.

Melaleuca. (Myrtaceae) Paperbarks are shrubs and small trees, some of which form extensive stands in and around wetlands. They are a major habitat type around much of Australia providing shade, support for climbing plants, nesting sites and holding together fragile soils against erosion. Many of the wetland species tolerate shallow to deep flooding for prolonged periods of time, but will be weakened gradually if their roots don't have a drier period. A healthy stand is an almost guaranteed sign that the wetland it is growing in dries out completely almost every year. The timber is quite hard and was used for building and some types of tools; the papery bark of some species was used as a lining for canoes and roofing. All are readily propagated from seed sown onto moist to wet soil.

Along the warmer eastern coast of Australia, *M. quinquenervia* is the dominant species, a tall and handsome tree that may cover huge tracts of ground (and has become a serious weed after introduction to Florida in the USA). It is replaced further south by *M. ericifolia* and *M. squarrosa*, and in turn *M. halmatutorum* becomes more frequent in saline wetlands from southern Victoria to Western Australia, where *M. rhaphiophylla* is the freshwater equivalent. Another distinctive suite of species dominates in tropical wetlands, including *M. cajuputi*, *M. dealbata*, *M. leucandendra* and the widely distributed and adaptable *M. viridiflora* (see Colour Plate 18b).

Melastoma. (Melastomataceae) Purple tongue (*M. affine*) is an attractive, brittle shrub found in wetland fringes in warmer areas. It is readily propagated from cuttings of hardened new growth in a glasshouse, or from seed sown onto warm, moist soil. The purple fruit is edible.

Mentha. (Lamiacaeae) Native mints are low-growing herbs of wetland fringes and river banks, rather than true wetland species. They have been used medicinally and to flavour foods, and are all fairly shade tolerant. Propagation is by seed sown onto moist to wet soils, from cuttings, or by division.

Microcarpaea. (Scrophulariaceae) *M. minima* is a creeping, tropical herb found on mud and in shallow water, often on sandy soils. It is usually propagated by divisions or cuttings, but also grows as an annual in drier places where it sets generous crops of seed.

Mimulus. (Scrophulariaceae) These are creeping or upright herbs of shallow waters and wet soils, with attractive and showy monkey-faced flowers. Most are easily grown from cuttings and division, or from seed sown onto wet to waterlogged soils. The exception is *M. repens*; this species is very salt tolerant, and requires the addition of some lime and clay to its soil for reliable growth.

Monochoria. (Pontederiaceae) These are sprawling to upright, tropical to subtropical herbs of shallow waters, with attractive columns of blue or sometimes white flowers (see Colour Plate 24b). Plants may be annual or perennial depending on growing conditions, and propagation is easy by division early in their growing season even for annual forms. Seed sown in shallow water or in waterlogged conditions will germinate after a few months in warm conditions, but comes up erratically and should be in full sun or plants may be prone to fungal problems – a trace of salt in their water will also help minimise this.

Mosses. Many species of mosses are found in and around wetlands, or even growing underwater in streams. Identification is difficult in many cases unless they are producing spores (Meagher & Fuhrer, 2003 is the best identification guide), and propagation is always by division, replanting into conditions as close as possible to those they were collected from. Few mosses will thrive in the relatively raw conditions of a created wetland. See also *Sphagnum*.

Muehlenbeckia. (Polygonaceae) Tangled lignum (*M. florulenta*) forms extensive thickets in seasonally flooded areas, and is a major habitat type in its own right. It is very drought tolerant once established and will grow even on clay. Propagation is easy from seed sown in moist to wet conditions. Young cuttings will take root fairly readily, but note that plants are either male *or* female, so cuttings from both sexes should be included in wetland plantings.

Murdannia. (Commelinaceae) Closely related and ecologically similar to *Commelina*, also propagated in the same ways.

Myriophyllum. (Haloragidaceae) Water milfoils include many important species that provide underwater shelter for diverse invertebrates, tadpoles and young fishes, particularly in more ephemeral waters although some prefer deeper and more permanent waters. Many of the larger species respond well to high nutrient levels, and have potential for water treatment. Most of these are tolerant of some shade and also of moderately saline waters.

All are readily grown from cuttings, although *M. salsugineum* can be slow to put out roots initially (see Colour Plate 25a). Seed is sometimes produced abundantly and will germinate readily in clear, shallow waters and even on waterlogged soils. The smaller, annual species are more difficult to establish, needing a combination of exposed soil with a fine silt layer, no competing vegetation, and a well-defined dry period.

Najas. (Najadacaeae) Water nymphs are submerged annuals and perennials usually found in fairly permanent waters, and are tolerant of moderate to fairly high salt levels. *N. marina* can be quite invasive, forming choking tangles of vegetation, and is best not used where it can spread widely. They are usually propagated by division or by cuttings taken when in full growth.

Nelumbo. (Nelumbonaceae) Sacred lotus (*N. nucifera*) is a spectacular, umbrella-leaved plant with large flowers, and is found across Asia into northern Australia, forming extensive stands in deep to shallow tropical waters. Unlike the very different horticultural clones introduced from northern China (sometimes via Japan), indigenous forms do not seem to recognise cold autumn conditions as a signal to produce dormant tubers, so they are usually killed by frost. Instead, their dormancy seems to be triggered by increasingly hot conditions and falling water levels.

A cultivated clone called 'Paleface' is reputed to be Australian in origin, but its petal shape, flowering responses and distinctive dormant tubers all unequivocally place it with the northern Chinese forms, which are also known to be genetically distinct. Lotus tubers and seeds are highly regarded as food in South-East Asia.

Propagation is by division of the runners, preferably just before they come out of dormancy, which in northern Australia is at the beginning of the wet season. The hard-shelled seed is easily germinated in warm (25°C plus), shallow, nutrient-rich soils, after filing through the hard, dark seed coat to expose just a hint of the pale embryo within. Seed viability of the northern Chinese lotuses is known to be six centuries or more, but may only be a matter of decades in thinner-shelled Australian forms, and Surrey Jacobs has had recently collected, dry-stored seed from the similar New Guinea lotus spontaneously germinating without anything being done to the seed coat.

Neopaxia. (Portulacaceae) Water purslane (*N. australasica*) is a running herb of shallow waters and wet soils, forming extensive lawns in some places. This fast-growing species responds well to fertilisation and has considerable potential for water treatment; it will also tolerate moderate shade. It is readily propagated by division, and by seed sown onto waterlogged soil.

Nitella. (Characeae) These algae are closely related to *Chara*, although they are generally smaller and finer. The information under that genus applies equally well here.

Nymphaea. (Nymphaeaceae) All native waterlilies are tropical species, growing in fairly deep but often ephemeral waters and often in extensive stands that help stabilise water temperatures below (see Colour Plate 25b). They provide shelter, seed and edible leaves for a wide variety of animals, and their stems, tubers and flowers have been eaten by humans. Best growth is on silty soils rich in organic matter, with some nitrogen available (blood-and-bone is a convenient source) as they are heavy feeders if given the opportunity. Seed will germinate readily in warm (25°C plus), clear, shallow water, the young plants being moved deeper as they grow. Tubers of some species also produce offsets that will become new plants if separated.

Nymphoides. (Menyanthaceae) Marshworts are creeping herbs of deep to shallow waters, with floating leaves similar to *Nymphaea* in shape, hence their Latin name (see Colour Plate 26a). The smaller, annual species are usually found in shallower and more ephemeral habitats, but even the large perennial species may disappear from a habitat which has dried out for too long, and regrow from seed after the first heavy rains. Marshworts can form extensive tangles and are significant as underwater habitat, particularly as shelter from predatory birds above, and diving birds below the water. Like *Nymphaea*, they will help stabilise water temperatures below the extensive surface layer of leaves.

Most species respond well to fertilisation and probably have some water treatment potential. Propagation is simple by division and by node cuttings of the floating stems. Seed of many species is also produced abundantly and germinates readily if it is dried for some time, then wetted to crack the seed coat.

Nypa. (Arecaceae) Nypa palm (*N. fruticans*) is an unusual mangrove species which may form extensive groves in tropical areas, although these are not as common in Australia as in parts of Asia. Unlike true mangroves, it adapts to a wide range of salinities and will even grow in still, fresh water. The branching underground trunks can be divided if large specimens are needed quickly, although casualties can be high. Fresh seed germinates readily but slowly, and needs constant heat for good results.

Oenanthe. (Apiaceae) Water dropwort (*O. javanica*) is a celery-like herb found in shallow tropical waters in northern Queensland, and also extends as far north as Japan where young tips are commercially harvested and eaten in winter. It is easily propagated by division.

Oldenlandia. (Rubiaceae) These are annual, tropical herbs of shallow waters and wetland fringes, flowering and setting seed as the soils on which they grow dry out.

Ondinea. (Nymphaeaceae) *O. purpurea* is a curious waterlily relative found only in the Kimberleys, growing in waterholes in the sandy beds of ephemeral creeks. Plants form tubers as water levels fall, and these were eaten by Aboriginal peoples. Tubers have been separated to multiply stocks in cultivation, but are sensitive to fungal and bacterial attack, so *Ondinea* is best protected and left to look after itself in its specialised native habitats.

Orchids. Some indigenous orchids grow in seasonally moist to wet, but rarely flooded places, including various greenhoods (*Pterostylis*), sun orchids (*Thelymitra*) and bird orchids (*Chiloglottis*). It is a fair stretch to describe these as wetland plants, and the complexities of their propagation whether from seed or tubers, and of reintroducing them into suitable habitat are best accessed through the voluminous literature on this family. See also *Phaius*.

Oreobolus. (Cyperaceae) This is a group of mat-forming sedges found in and around alpine bogs, growing with *Sphagnum* and other low-growing plants. They are easily propagated by division, or from seed sown onto wet, peaty soil.

Oryza. (Poaceae) These wild, mostly annual grasses are closely related to edible rice; some are short-lived perennials in suitable conditions. The seed of these grasses has long been eaten by humans and many other animals, and *O. rufipogon* which is also found in Asia may be ancestral to cultivated rice (see Colour Plate 26b). All wild rice (distinct from the North American wildrice, *Zizania*) species can form extensive stands in shallow, ephemeral, tropical wetlands, where they are often a major habitat component. Propagation is from seed which needs dry storage for some months before planting.

Ottelia. (Hydrocharitaceae) In warm waters both native species are attractive, short-lived perennials with broad submerged or floating leaves, and showy flowers which open at the surface. However, in cooler climates and ephemeral wetlands they grow as annuals. They are eaten by many waterbirds and they will also disappear rapidly if water snails are present in any numbers – and they are also killed by the copper cure used to treat snails in cultivation!

Best results for propagation of the more widely distributed *O. ovalifolia* are from fresh seed planted in warm, shallow water on fine silt (see Colour Plate 27a). Reports of propagation by division are in error, and are based on a misinterpretation of how it grows – the seed germinates as the seedhead it is contained in disintegrates, so seedlings often come up in tightly clustered and intertwined groups which are easily teased apart. A close examination of these will show that there is never a connection between the individual crowns.

O. ovalifolia has long been toyed with as an ornamental pond plant, but after two decades of experimentation in southern Australia I now only produce it for special orders, as it appears to be mostly a vagrant species this far south. Ironically, the largest plants may be found in the shallows of cattle-trampled dams, where the combination of manure-rich silt and the shallow layer of hot water just below the surface (heat and light don't penetrate far in such murky waters) recreate the warm conditions it prefers further north. The more tropical *O. alismoides* has even more handsome, crinkled leaves, but is even more difficult to transplant except at a very young age.

Pandanus. (Pandanaceae) *P. aquaticus* forms extensive, suckering stands on tropical floodplains, and is usually flooded during the wet season. This is a major habitat plant, providing shelter for a wide variety of animals (see Colour Plate 27b). Where water buffalo are common, they destroy many of the suckers, so this species now often grows as single trunks. Fencing buffalo out will allow suckers to regrow and increase the habitat value of this plant, but is not practical except on a relatively small scale. However, the giant Diprotodons (wombat-relatives which have only become extinct fairly recently in geological terms) may have caused similar damage, so buffalo may just be their ecological equivalent. This plant can be propagated from fresh seed buried in moist to wet soil, or from suckers, although this is labour intensive.

Panicum. (Poaceae) These are annual or perennial grasses, some of which are found in ephemeral waters and on the fringes of wetlands. Propagation of most species is straightforward from seed after a dry, dormant period; perennial species are also easily grown from divisions.

Paspalum. (Poaceae) Water couch (*P. distichum*) is possibly introduced, and forms a dense mat on disturbed ground along the fringes of wetlands, where it can grow so thickly that all other low-growing plants are smothered. In relatively undisturbed wetlands it usually grows much more sparsely, but in either situation there seems no particular reason to deliberately introduce it. It is easily raised from seed sown on wet but not waterlogged soil.

Pennisetum. (Poaceae) Swamp foxtail-grass (*P. alopecuroides*) is dubiously native in Australia, and most plants sold under this name until fairly recently were the introduced *P. setaceum*, a proven weed. It is easily raised from seed, but should not be used in wetland plantings.

Persicaria. (Polygonaceae) These sprawling or upright herbs of shallow, ephemeral waters form extensive thickets in some places (see Colour Plate 28). Most species respond fairly well to high nutrient levels, and have potential in water treatment. They are all fairly shade tolerant. Propagation of the wetland species is easy from fresh seed planted on wet to waterlogged soil, and from cuttings or divisions.

Phaius. (Orchidaceae) Swamp orchids are the largest-flowered terrestrial orchids in Australia, and although they are mainly associated with the fringes of wetlands (and often grow on higher, drier ground) are included here as over-collecting has considerably reduced their range. Unlike most native terrestrial orchids, these large plants are easily propagated by separating divisions. Established plants in pots will often produce small seedlings growing around their roots, so keeping a group of unrelated plants together in a warm, shaded greenhouse is potentially a way of salvaging some of the genetic diversity lost in past years. It is now illegal to collect these plants from the wild, but as there was a flourishing trade in wild-harvested plants not much over a decade ago, it is still not difficult to assemble a few unrelated swamp orchids by legal means.

Philydrum. (Philydraceae) Woolly frogmouth (*P. lanuginosum*) is a curious plant with spongy leaves resembling those of an iris, and woolly columns of yellow flowers (see Colour Plate 29a). Used in Chinese medicine (I have been unable to decipher the text to find out for what!) and tolerant of shade, it responds well to high nutrient levels. Propagation is easy from the prolifically produced seeds, sown onto waterlogged soil or into very shallow water; divisions also grow readily.

Phragmites. (Poaceae) Reeds form extensive stands which are a major habitat type, though a rather limited one as they crowd all other plants out and very few birds or larger animals are found far inside the perimeter of larger patches. They have been used as roof thatching, to make paper, for grazing, and the young shoots are edible. Both native species are also fairly salt tolerant, drought tolerant when established, and survive moderate wave action.

Reeds have been used extensively in water treatment overseas, an example that has been followed uncritically in Australia. In the bitterly cold winter climates of the Northern Hemisphere, *Phragmites* and *Typha* (see the entry later in this chapter) are the only large wetland plants widely available, which is why they have been extensively used and studied. However, the common species *P. australis* is dormant for a large part of the year, when it does nothing much in the way of absorbing nutrients. It would be more sensible to research the wide variety of fast-growing, nutrient responsive, *evergreen* plants available in Australia than to assume that reeds are the best option in Australia's diverse climates.

Propagation can be done in spring by division when growth begins, producing large plants quickly but with much labour. Seed will grow readily after a few months stored dry, but should be separated from the feathery flowerheads before planting. Alternatively, the mature flowerheads can be laid out over the propagating mix during the winter months, relying on rain to wash out any germination-inhibiting chemicals present. Not all populations of reeds seem to set viable seed, so test a number of populations (particularly where a few patches are found in close proximity) to be sure that this method will work.

Where reeds need to be controlled or reduced in numbers, a combination of burning or slashing while water levels are low, followed by grazing of new growth will set them back considerably. If this is done several months before plants would normally die down, the stand can be set back dramatically in a single season, and eradicated by the end of the second growing season.

Pilularia. (Marsileaceae) *P. novae-hollandiae* is a tiny, grass-like fern. It is propagated by division, although the remarks on spore propagation under the related *Marsilea* may also apply here.

Pistia. (Araceae) Water lettuce in floating, leafy rosettes can form a choking blanket over smaller bodies of water. It is probably only native in NT and is declared noxious in NSW. It may have some value in water treatment, tolerates some shade, and reproduces rapidly from offsets at temperatures above 15°C.

Poa. (Poaceae) Various species of these tussocky grasses have been widely used in wetland plantings, and just about everywhere else as well. Although attractive enough they are mainly found in seasonally wet drains and drier soils rather than true wetlands. They are easily raised from seed.

Pogostemon. (Lamiaceae) *P. stellatus* is an annual herb of tropical wetlands, with attractive pink flowerheads. It only grows in areas that dry out for part of the year, although occasional seedlings can be found in deeper waters, and is not hard to raise from seed.

Polygonum. (Polygonaceae) *P. plebeium* is a creeping annual of shallow, ephemeral waters and wetland fringes, flowering and fruiting as the mud it grows on dries out, and easily raised from seed.

Posidonia. (Posidoniaceae) This is the most grass-like of the seagrasses, forming extensive meadows underwater. Its fresh seed germinates readily; divisions may be successful but are slow to re-establish.

Potamogeton. (Potamogetonaceae) Pondweeds can form extensive submerged stands, mainly in deeper, more permanent waters (see Colour Plate 29b). Most are fairly salt tolerant, will grow well even with some shading, and have moderate potential for water polishing in low nutrient situations. Some produce turions or tubers that are eaten by many waterbirds, as are the soft, submerged leaves and sometimes the seeds. In hotter conditions, some may grow as annuals.

Pondweeds can be propagated by division early in their growing season from spring to early summer, and sometimes from cuttings – although this is unreliable. Seed can be sown in clear, shallow water even though its germination rate is not usually impressive, and winter-dormant turions or tubers give more reliable results for *P. crispus* and *P. ochreatus*. One unpublished report suggests seed germination is improved by passing through a duck's digestive system, but my own tests suggest that very few seeds survive the journey, and collecting and planting the resulting foul ichors is not a job for the faint-hearted! See also *Stuckenia*.

Pratia. (Campanulaceae) See *Lobelia*.

Pseudoraphis. (Poaceae) These are creeping grasses of wetland fringes, forming extensive carpets in places. Mudgrasses are moderately salt tolerant, and will grow on clay. Spiny mudgrass or moira grass (*P. spinescens*) is particularly widespread in inland areas. All species are easily propagated from seed sown on waterlogged soil after several months of dry storage, or by division.

Pycnosorus. (Asteraceae) These are closely related to and very similar to *Craspedia*; the information under that genus applies equally well here.

Ranunculus. (Ranunculaceae) Some native buttercups grow in shallow waters, or at the seasonally flooded edges of wetlands where they form dense, shade tolerant carpets at the water's edge. All species respond well to high nutrient levels, so they have potential in water treatment. A few species such as *R. diminutus* tolerate moderately saline soils as well as waterlogged conditions. The aquatic species form useful underwater habitat for invertebrates, tadpoles and spawning fish. Propagation by division is easy, and submerged plants can usually be multiplied from cuttings of the floating stems.

Restio. Although some Australian plants were once regarded as part of this South African genus, these have all been reclassified. See *Baloskion*, and also 'Cordrushes' in the introductory section of this chapter.

Rhynchospora. (Cyperaceae) The Australian representatives of this genus are mostly tall to very tall, upright tussocks found on floodplains and along streams, where they may form extensive stands (see Colour Plate 30a). They are easily grown from seed sown onto moist to wet, preferably not waterlogged soil, or from divisions when large plants are needed quickly.

Riccia. (Ricciaceae) These are tiny, much-branched, floating liverworts that only reproduce sexually in their stranded stage. They are shade tolerant, and easily propagated by division.

Ricciocarpus. (Ricciaceae) *R. natans* is a curious, floating liverwort with a black, root-like beard below. It is shade tolerant, and sometimes forms dense carpets in isolated, smaller pools in wetlands but never grows as thickly as *Azolla*. It multiplies itself readily even from a single piece.

Rotala. (Lythraceae) *R. mexicana* is the most aquatic of this group of tropical plants from ephemeral wetlands, where it is often annual, flowering and setting seed as water levels fall. It can be grown from seed planted in warm, shallow, clear waters or from cuttings taken long before flowering begins.

Rumex. (Polygonaceae) Most native docks grow in seasonally wet places rather than in wetlands, but some are also found in areas that may be flooded for weeks or even months. They will grow on clay, tolerate some shade, are fairly drought tolerant and their seeds are eaten in moderate numbers by some waterbirds. Water dock (*R. bidens*) is the most aquatic species, growing even in permanent shallows. All species are readily propagated by seed sown on wet soil, or from divisions.

Ruppia. (Potamogetonaceae) Sea tassels and widgeon grasses are slender-leaved plants that grow in a wide range of salinities, from fairly fresh waters to water saltier than the sea (see Colour Plate 30b). They are among the few plants present in some deeper saltmarshes, and their seed and leaves are probably a major source of food for plant-eating waterbirds. Sea tassel (*R. megacarpa*) is perennial and is not hard to establish on silty soils in moderately saline water. The annual species can only be raised from seed sown in shallow water, although young plants may also grow if separated before their roots are too entangled.

Samolus. (Primulaceae) *S. repens* is a creeping plant of saline soils, growing in seasonally flooded areas (see Colour Plate 18a). It is easily grown from cuttings or divisions, and from seed sown onto waterlogged soil with some lime added.

Sarcocornia. (Chenopodiaceae) Glassworts are succulent, creeping plants of saltmarshes and estuaries, growing on wet soils that may flood frequently. They often form extensive stands and are a significant shelter habitat for many smaller animals, and indirectly for the many birds which feed across glasswort flats at higher tides. Propagation is not difficult from cuttings, but newly planted areas must be protected from disturbance for many months, preferably even for years. Divided plants survive more reliably but take time to recover from surgery.

Schoenoplectus. (Cyperaceae) Clubrushes are medium-sized to tall sedges that grow in moderately deep to shallow, sometimes ephemeral waters, where they may form extensive stands (see Colour Plate 31a). They are often seen as part of a diverse patchwork of wetland species, and excessive planting will reduce their usefulness as habitat. All native species are moderately salt tolerant, will grow on clay, and the larger species can survive some wave action. They respond well to high nutrient levels, and have considerable potential in water treatment. However, many southern species are also markedly seasonal in their nutrient uptake, and are probably not much more useful for water treatment than *Typha* or *Phragmites* for this reason. Propagation by division is labour intensive, but seed is copiously produced and most of it will germinate if planted onto waterlogged soil, at the time the plants would normally start growing in wild populations.

Schoenus. (Cyperaceae) Bogrushes are small sedges of wet places including peaty heathlands, and shallow, ephemeral waters. Some will grow on clays, and will tolerate a fair degree of shading. They are readily propagated from seed sown onto wet soil if you have the patience to harvest it, or by division. Annual species such as the variable and widespread *S. apogon* are readily established from seed.

Scirpus. (Cyperaceae) *S. polystachyos* is a largely sub-alpine sedge similar in appearance and habit to the closely related *Bolboschoenus* species. The general remarks under that genus apply here also.

Sclerostegia. (Chenopodiaceae) See the closely related *Halosarcia*, which is also propagated in the same ways.

Selliera. (Goodeniaceae) This is a creeping plant of shallow, ephemeral and usually saline to very saline waters (see Colour Plate 31b). It will grow on clay, and tolerates some shade. It is advisable to propagate by division; seed collection is an inefficient process on these small plants.

Sparganium. (Sparganiaceae) The native burr-reed (*S. subglobosum*) grows in both deep waters and shallow, often ephemeral wetlands. It can form fairly large stands, and is probably a significant habitat plant in warmer areas where it is more abundant. It is usually propagated by division, but fresh seed will also germinate fairly well if sown onto waterlogged soil.

Sphagnum. (Sphagnaceae) These are alpine mosses sometimes forming extensive bogs on wet to waterlogged depressions in the high country, particularly in Tasmania. They are easily propagated from any living piece planted in suitable conditions, on wet peaty soils.

Spirodela. (Lemnaceae) See Duckweeds.

Sporadanthus. (Restionaceae) This is a small but widespread group of cordrushes found in sandy, seasonally flooded soils. Only one of these species sets seed with any reliability, and can be propagated as described for *Chaetanthus*, while the others can be propagated by division with extreme care in timing – see the remarks on ‘Cordrushes’ at the beginning of this chapter.

Sporobolus. (Poaceae) These are fringing grasses of saline wetlands and tidal zones, often forming dense stands. They are easily propagated from seed, with attention paid to harvesting from higher and drier ground for planting in drier situations, and closer to the tidal fringes for wetter plantings, as there may be genetic differences even over short distances in *S. virginicus*.

Stenochlaena. (Blechnaceae) Swamp fern (*S. palustris*) is a climbing, fast-spreading, colonising fern of wet, seasonally flooded places in the tropics. It usually spreads by spores that are produced on a considerable scale, and will grow even on clay. After the massive meteoric impact which finished off the dinosaurs and wiped most North American forests off the map, spores of close relatives of *Stenochlaena*, possibly looking and growing similarly, became the most common plant fossils for a time as they colonised the newly devastated lands. Swamp fern is also easily multiplied from cuttings of the climbing stems, and the richly red young fronds are a sought-after vegetable in South-East Asia.

Sticherus. (Gleicheniaceae) See the closely related *Gleichenia* which grows and is propagated similarly (see Colour Plate 21a). However, fan ferns are usually easier to propagate by division than the coral ferns.

Stuckenia. (Potamogetonaceae) Sago pondweed (*S. pectinata*, synonym *Potamogeton pectinatus*) is so called for its large, sago-like seeds that are eaten by many birds in saline marshes, though it will also grow in fresher waters. It is easily confused with *Ruppia* when not in flower or fruiting, and may grow almost as densely in ideal conditions. Its seed doesn’t germinate any more reliably than for the other pondweeds, but the small tubers formed in large numbers just before winter dormancy (also a favoured waterbird food) will each become a new plant if separated and spread out.

Suaeda. (Chenopodiaceae) Austral seablite (*S. australis*) is a soft, succulent plant of saltmarshes, usually growing on slightly higher ground where it is rarely flooded but can tap into a reliable water source further underground. Cuttings are prone to fungus if grown in purely fresh waters, but small seedlings appearing in mats near the parent plants are easily teased apart and grow more reliably.

Swainsonia. (Fabaceae) *S. procumbens* is a sprawling pea relative found in seasonally flooded depressions and at the edge of more ephemeral wetlands, often in heavy clay soils. The seed needs treatment with 30 seconds immersion in near-boiling water, after which it should be kept wet for a day before planting. For smaller numbers of seeds, nicking through the seed coat of each one will give more uniform and reliable germination.

Tapheocarpa. (Commelinaceae) The recently described *T. calandrinioides* from around the Gulf of Carpenteria is close to *Commelina* and can be propagated similarly from seed or root divisions. However, the developing fruits can be buried or pushed into mud as they mature and probably require darkness as well as water for germination. It will act as an annual in extreme drought conditions, or may be a short-lived perennial in permanently wet soils.

Todea. (Osmundaceae) King fern (*T. Barbara*) is a very large and slow-growing fern found along stream banks, and in spring-fed wetlands where there is enough water movement to bring oxygen to the roots (see Colour Plate 32a). It is shade tolerant and very long lived. Propagation is not difficult from spore as long as this is sown immediately after harvesting so there is no chance of it drying out, but this method is very slow.

Tremulina. (Restionaceae) These are two species of Western Australian cordrushes from wet, sandy places. Both species can easily be propagated from seed, or by division while they are actively growing. Plantings done from division should include male and female plants for future seed production.

Triglochin. (Juncaginaceae) There are a few smaller, annual species in this genus that are mainly found on seasonally wet, often saline soils around the fringes of wetlands. Little is known about their propagation although they are likely to germinate well from seed sown onto moist soils in autumn. *T. striatum* is a larger, perennial and very salt-tolerant relative that varies from being cylindrical-leaved to a flat-leaved form often found in somewhat fresher waters. This species grows in shallow, often thoroughly stagnant ephemeral waters, and is easily propagated by division or from seed on waterlogged soil.

The most conspicuous and ecologically important *Triglochin* species are the eight known as water ribbons (subgenus *Cycnogeton*), although until fairly recently these had been lumped together under one name: *T. procera* (see Colour Plate 32b). The widespread plant of south-eastern Australia still known by this name is perhaps the most salt tolerant of the *Cycnogeton* group, flourishing even in the upper tidal reaches of estuaries. It is also still the most variable of the group as presently defined, including two or perhaps three distinct forms that may later be regarded as species in their own right.

These larger, strap-leaved plants are common in a wide range of deep to shallow wetlands, or even in moving water, from Perth to Sydney, then northwards along the east coast to New Guinea and the Northern Territory. Regardless of species or form, the group as a whole provides food in the form of leaves, seeds and tubers, as well as shelter both above and below water for many animals from invertebrates to waterbirds. Their sweet, starchy tubers are edible and the best of our wetland bush-tucker foods, although those of *T. microtuberosa* are too small to be worth harvesting. Tuber size varies even between populations of any one species, and selected forms could perhaps be hybridised to give larger crops.

All tuberous *Triglochin* are very drought tolerant once established, and absorb nutrients like a sponge so they are excellent for water treatment. The underground tubers are formed as water levels fall, and carry the plant through dry periods.

Most species will not flower or produce seed until they recognise that the water they grow in is deep enough to give seeds a good chance to grow into small plants (and form their own tubers) before the next dry period. This extreme adaptation to drought is why many populations of water ribbons may only flower once in a decade, or even less, though they will grow every year if there is enough rain to wet the ground thoroughly.

The widespread *T. dubia* is the most drought tolerant, found from central Victoria to New Guinea. I have lifted root balls of this species from a floodplain in northern Victoria where they had been completely dormant for six years, and they were putting out new leaves within two days of being placed in water. The Northern Territory version of this species is markedly different in appearance, and survives in an even wider range of conditions from 2 metres deep in running waters during the wet season to baking-hot, bone-dry creek beds for months before the rains return.

Larger plants resent disturbance and take some time to recover from being lifted and divided. Fortunately, propagation is easy from fresh seed sown on waterlogged soil or into clear, shallow water. The seed is ready to harvest when it comes off readily in the hand, except in *T. rheophilum* in which seeds may germinate while still attached to the flower stalk, an adaptation to the fast moving waters it is found in. As seed is greedily eaten by many waterbirds it may need to be collected a few days before this stage, but will ripen, then sink and germinate if floated for a month or two in clear, shallow water.

Typha. (Typhaceae) Native species of cumbungi form extensive stands in both deep and shallow, often ephemeral waters, and even in clay-lined drains. They are a major habitat type, but a very limited one, crowding out most other types of plant growth through sheer size, and possibly also allelopathy. *T. domingensis* is less aggressively spreading than *T. orientalis* as it is generally smaller, while *T. orientalis* is often a much larger plant and can reach 3 metres high.

Both native species are colonising plants adapted to disturbed conditions, and will even grow on the compacted clay of new dams, where they usually become a problem within a decade or two. Their dried rhizomes yield a good quality flour, the abundantly produced pollen can be used to make a type of bread, and the young shoots are also edible. Because of their large size they are fairly tolerant of wave action.

Typha species have been planted for water treatment in Australia (see also the discussion of water treatment under *Phragmites*), but only a handful of misguided souls have used it in recent years. Propagation is all too easy from seed sown onto waterlogged soil; this germinates within days and needs to be pricked out quickly as growth is rapid. The seedlings are very small initially, and don't germinate or grow well in wetlands with dense established plantings of competing plants.

In most cases control is more desirable than planting. This can be done by slashing, ideally when the flowerheads are maturing, and just before pollen is shed from the male head above. At this stage, much of the energy reserve of the plant is concentrated above ground. Follow up the initial slashing with flooding or grazing, preferably both if possible. Domestic geese are particularly good at destroying the young shoots which follow (black swans are even better if you can get hold of a ute-load), or in deeper waters the soft new shoots are easily pulled by hand just as they reach the surface.

Urtica. (Urticaceae) The native scrub nettle (*U. incisa*) often grows in seasonally flooded areas and on the fringes of wetlands, even floating out over deeper water. It tolerates quite deep shade, and propagation is easy by division; seed sown onto moist to wet soil will also come up readily.

Utricularia. (Lentibulariaceae) Aquatic bladderworts are floating plants with bladder-like traps used to catch minute underwater animals. They are found among taller plants in quite shaded conditions, but are also tolerant of full sun. Although these species are often found in acid waters, *U. australis* at least seems unaffected by quite alkaline conditions. *U. gibba* has been widely spread with pond plants, and though it is indigenous in warmer parts of eastern Australia, is appearing in wetlands further and further south of its native range. Propagation of the floating species is by division, or from the turions formed when the plants are dying away in winter.

Semi-aquatic *Utricularia* species are sometimes referred to as fairy aprons for the shape of their flowers, and grow at the fringes of wetlands (especially smaller ones) in fairly peaty soils. These creeping plants flower as water levels fall, and are propagated by seed or division. Some can be propagated more rapidly by keeping them flooded to around 5 mm depth, as they spread faster in their submersed form.

Vallisneria. (Hydrocharitaceae) Ribbonweeds or eelgrasses are grassy plants of deep to moderately shallow waters, spreading rapidly by fine runners. They are eaten by a wide range of waterbirds, and will grow on a layer of fine silt over clay or sand, and even in deep shade. Most respond well to fertilisation and are very useful in water treatment where nutrient levels aren't so high that the water turns green from algae. Fruits with viable seeds are only found infrequently in most populations of perennial eelgrasses, so propagation is generally by division.

The more tropical, annual species, particularly *V. caulescens*, can be multiplied by seed sown in clear waters over naturally accumulated silt, while *V. annua* may become a perennial in more permanent waters. The closely related annual *Maidenia* is similarly propagated, and there are intermediate plants which suggest that the two genera are more closely related than has previously been thought.

Villarsia. (Menyanthaceae) Marshflowers are creeping or clump-forming herbs of shallow, ephemeral waters, flowering as water levels fall. Most will grow on clay, tolerate fairly to deeply shaded situations, and are very drought tolerant once established. Plants can be divided, or propagated from seed as described under *Nymphoides*. Erect marshflower (*V. exaltata*) has two types of flower, neither of which pollinates its own kind readily, so both types should be included in any planting done by division of this species.

Wilsonia. (Convolvulaceae) These are creeping saltmarsh plants from seasonally waterlogged places, which become increasingly dry or even arid by autumn. They are usually grown from cuttings or divisions.

Wolffia. (Lemnaceae) See Duckweeds.

Xerochrysum. (Asteraceae) Swamp everlasting (*X. palustre*) is a curious, papery-flowered daisy that grows around the seasonally flooded fringes of some ephemeral wetlands in south-eastern Australia. It is usually propagated from divisions of the underground runners.

Xyris. (Xyridaceae) Perennial yellow-eyes, including *X. operculata* and *X. gracile*, are slender-leaved, grassy-looking tussocks of peaty damplands that are sometimes waterlogged for weeks at a time in winter. Wild plants are difficult to establish from divisions, though potted plants with their better-established roots can be broken up into a few new plants when they are actively growing, as long as this isn't done too often. Fresh seed sown onto a wet mix of half fine sand, and half peat with some blood-and-bone as fertiliser will germinate readily.

Other, more tropical species such as *X. indica* are annuals and can only be grown from seed, though seedlings are difficult to establish in the shallow, moving floodwaters they seem to favour.

Zannichellia. (Zanichelliaceae) The fine, tangled underwater mats of *Z. palustris* are tolerant of fairly saline conditions, and are easily propagated by division of the roots, or sometimes from cuttings.

Zostera. (Zosteraceae) These seagrasses often form extensive underwater meadows. The mature 'flowerheads' break off and release seed that germinates soon after; plants can also be divided but are slow to re-establish by this method.

Glossary

allelopathy: production of substances by a plant that adversely affect the ability of other species of plants (and sometimes animals) to grow.

annual: a plant that grows for a year or less, setting seed as it dies.

artesian waters: underground waters brought up from some depth, used in drier areas as a source of stock and irrigation water, but usually very hard.

by-wash: see overflow.

catchment: the land surface from which the water to a dam or wetland runs off and is collected.

clone: genetically identical plants, whether one very large stand spread over many hectares, or many smaller plants obtained by division or cuttings from a single parent.

cultivar: a particular clone of an ornamental plant, often with its own cultivar name.

dampland: an area where the water table rises to very close to the soil surface during some times of the year.

drawdown: lowering the water level in a wetland, sometimes used as a management method for controlling weeds or vermin.

emergent: parts of a plant growing above water.

ephemeral: in wetlands, a body of water that regularly dries out for a part of the year.

estuary: the section near a river or creek mouth where sea and freshwater mix.

exotic: introduced from another area, usually another country in the sense used here.

genetic drift: an in-breeding effect that happens when a very small number of plants (especially from a single seed) colonise a wetland, and reproduce to form a closely related population which may be somewhat different (drift away from) the norm for that species.

germination: in seeds, sprouting.

groundwater: underground water (see also water table).

guild: a group of plants often found growing together, suggesting some degree of mutual compatibility.

hardness: a measure of the quantity of calcium, magnesium and other salts present in water, other than sodium salts (see also salinity).

hydrologist: a person who studies the ways in which water moves through wetlands and underground.

indigenous: a plant native to a particular area, that is one that has not been introduced from elsewhere.

ionic: in the simplified sense used in this book, a soluble form of a chemical, usually a metal.

levee: an earth bank used to divert waters in new directions, or hold back flood waters.

mangroves: trees or shrubs adapted to living in areas where water levels rise and fall with sea tides, and salinity can vary from almost pure seawater to freshwater at different times.

mycorrhizal fungi: diverse types of fungi associated with plant roots, helping with water and nutrient uptake, and often essential to the health of the plant. Some mycorrhizal fungi are associated with a wide range of plants species, while others form more specific partnerships.

overflow: a section of embankment that is made a little lower than the rest, where excess run-off water leaves the dam rather than just over any random part of the wall. Sometimes called a by-wash.

peat: plant matter that has only partly decomposed because of the absence of nitrogen and some other nutrients; it is very absorbent so it acts as a water store in swampy soils.

perennial: a plant that normally lives for years, as opposed to annual.

pH: a scale used to compare acidity or alkalinity, centred around a neutral point of 7. pH readings below 7 are increasingly acid as numbers go down, above 7 are increasingly alkaline as numbers go up.

ppm: abbreviation for parts per million.

pricking out: separating small seedlings (or proliferations) that have been growing very close together to save space during the germination stage, and planting them out individually.

proliferation: when plantlets form in the seedhead while still attached to the parent plant; these can be detached and planted as for seedlings.

rhizome: an underground stem.

salinity: a measure of the quantity of sodium salts present in water (see also hardness).

substrate: any soil or solid artificial mixture in which plants are grown.

sucker: a new shoot or growth coming up from the base of a plant.

sumpland: a dampland where the water table rises up to and sometimes a little above the soil surface at some times of the year.

terrestrial: growing or living on land, rather than in water or very wet places.

water table: the upper surface of underground water that may rise or fall with the seasons. This can be located by digging down to the point where a hole fills with water to a certain level – the water 'table'.

Further reading

Recommended reading

A few particularly useful sources have been separated out here from the wider range of references which follows.

Bradley J (1988) *Bringing Back the Bush*. Lansdowne Press: Sydney. Describes the Bradley Method of tackling weeds in bushland, which can also be applied in wetlands. The section on reclaiming river banks while minimising erosion is particularly useful.

Brock M (1997) *Are there Seeds in your Wetland? Assessing Wetland Vegetation*. Land & Water Resources Research & Development Corporation: Canberra. Many wetlands that have been significantly altered or heavily grazed still have a considerable reserve of living seed in the soil. This booklet describes how you can assess what remains before considering importing plants or seed from elsewhere.

Cowie ID, Short PS & Osterkamp Madsen M (2000) *Floodplain Flora: A Flora of the Coastal Floodplains of the Northern Territory, Australia*. Australian Biological Resources Study: Canberra. Excellent guide to tropical aquatic plants in the Northern Territory, and also useful elsewhere in the tropics.

Duke N (2006) *Australia's Mangroves: The Authoritative Guide to Australia's Mangrove Plants*. University of Queensland: Brisbane. Definitive identification guide using high quality photography to separate closely related species.

Meney KA & Pate JS (Eds) (1999) *Australian Rushes: Biology, Identification and Conservation of Restionaceae and Allied Families*. University of Western Australia Press: Nedlands, WA. Despite the title this book has nothing to do with *Juncus*, but is the definitive work on the cordrushes.

Romanowski N (1998) *Aquatic and Wetland Plants: A Field Guide for Non-Tropical Australia*. University of New South Wales Press: Sydney. Photographic guide covering over 300 species with information on habitat values.

Romanowski N (2007) *Edible Water Gardens: Growing Water-Plants for Food and Profit*. Hyland House: Melbourne. Although this is primarily a worldwide guide to the uses and cultivation of every aquatic and water's edge plant grown for food, a quarter of the species are also indigenous in Australia (and many other species have become weedy here).

Saintilan N (Ed.) (2009) *Australian Saltmarsh Ecology*. CSIRO Publishing: Melbourne.

Sainty GR & Jacobs SWL (2003) *Waterplants in Australia: A Field Guide* (4th edition). Sainty and Associates: Sydney. Not the ideal field guide despite the title, with only 100 native species selected from around all of Australia. However, the coverage of introduced weeds (over a third of the species covered in detail) makes this book extremely useful for wetland managers. Includes a good summary of blue-green bacterial problems.

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