Managing Typha and Phragmites

Report from workshop held 16th June 2014

Editors: Jane Roberts and Heidi Kleinert

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

Acknowledgement of Country

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

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Special thankyou to all the presenters and participants that attended the event, in particular Lisa Adams, Damien Cook, Janet Holmes, Paul Rees, Jane Roberts, Randall Robinson, Will Steele and Andrea White.

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Flyer for Workshop

Introduction

On 16th June 2014, a workshop was held in Melbourne on *Typha* and *Phragmites*, two native wetland plants that can be a problem in wetlands and waterways, most commonly by impeding flow and by outcompeting other plants.

The purpose of this workshop was to bring together individuals already involved in managing or needing to manage *Typha* and *Phragmites*, and individuals with experience or knowledge of these wetland plants.

The format was invited presentations in the morning, and group discussion of case studies in the afternoon. The audience volunteered a number of instances of the difficulties of managing *Typha* and *Phragmites.* Four of these were used as case studies for group discussion.

Workshop Objectives

- Share knowledge of the ecology and management of *Typha* and *Phragmites*.
- Share knowledge of where people go for information on wetland management.
- Identify knowledge gaps in managing *Phragmites* and *Typha* that could inform applied research.
- Create a record of the presentations and discussion to make available to participants and more broadly to assist management decisions on *Phragmites* and *Typha*.

Workshop Details

Heidi Kleinert, Project Officer with North Central CMA, saw the need for such a workshop.

This arose out of field situations across northern Victoria, where, in response to environmental watering, *Typha* and/or *Phragmites* are expanding, and displacing other wetland plant communities and altering the mosaic of wetland habitats.

The workshop was developed collaboratively by Heidi Kleinert and Janet Holmes, Waterway Health, Department of Environment and Primary Industries. Financial support was provided by North Central CMA and the Department of Environment and Primary Industries.

Lisa Adams, of Lisa Adams & Associates, facilitated the workshop and documented the discussion.

Presentations

This section gives the four presentations made at the workshop. It uses the slides from the original presentations, but has additional text to give more detail and to cover remarks made by speakers.

Typha and Phragmites: Similarities & Differences

Jane Roberts

1: General Characteristics

Background

The two native species of *Typha*, Narrow-leafed Cumbungi and Broad-leafed Cumbungi, are very similar in appearance, and hard to tell apart. They are similar enough ecologically to be considered together, from the perspective of control and management.

Typha and *Phragmites* are both *tall emergent macrophytes*. For these plants, 'tall' means 2 m or more in height and 'medium' means 1-2 m.

Emergent macrophytes are found throughout Victoria, in wet-moist habitats. Some are tall, some are medium. All are perennial, and most are native to Australia. The asterisk * (panel, right) means not native to Australia.

Typha and *Phragmites* are the main problem species. These are tough plants to deal with. The key to their success is the underground part of the plant called the *rhizome*.

Tall Emergent Macrophytes

Common Reed *Phragmites australis*

Narrow-leafed Cumbungi *Typha domingensis*

Broad-leafed Cumbungi *Typha orientalis*

Jointed Twig Sedge *Baumea articulata*
Tall Club Sedge *Bolboschoenus fluviatilis*
Marsh Club Sedge *Bolboschoenus medianus*
Drain Flat Sedge *Cyperus eragrostis* **
Tall Flat Sedge *Cyperus exaltatus*
Common Spike rush *Eleocharis acuta*
Tall Spike-rush *Eleocharis sphacelata*
Giant Rush *Juncus ingens*
River Club Sedge *Schoenoplectus tabernaemontani*
Lesser Reed Mace *Typha latifolia* **

Typha and Phragmites are tough plants to deal with. This is because of their rhizome.

This talk is nearly all about the rhizome, because it is so important.

Emergent Macrophytes: General Characteristics

Emergent macrophytes are wetland plants (but are also found at rivers edge, weirpools, estuaries).

They are called *emergent* because the plants are rooted in the sediment, but the shoot (also called a *culm*) grows up through the water into the air.

Australian emergent macrophytes are perennials.

Once a seedling establishes, it expands laterally – and rapidly - through *clonal growth* and occupies an area. A wetland covered by *Typha* or *Phragmites* may have started off from just one or just a few seedlings, so may have just a few genetically distinct individual plants. The plant establishes at a new site either from viable seed arriving, or from vegetative fragments arriving.

Ecological strategy is to persist on site.

Tall Emergent Macrophytes General Characteristics

Monocots: principal families are Poaceae (grasses), Cyperaceae (sedges), Juncaceae (rushes), and Typhaceae (cumbungi)

Life-History: Nearly all perennial (very few exceptions)

Highly productive.
Habitat: Rooted in water-logged substrate, foliage in air

Canopy: annual (deciduous, high turnover) or persistent ('evergreen')

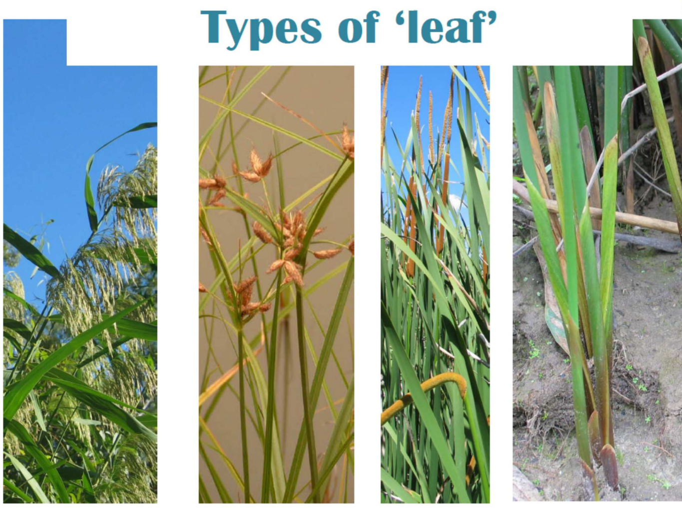
Clonal Growth. Stands may be few genotypes only

Strategy: Persist at a site through vegetative expansion, and competition. Rarely establish from seed

Leaves of Emergent Macrophytes

This is a quick look at leaves of emergent macrophytes, to showcase how different they can be (from left to right):

- Flag-like, attached to the shoot at various places up to the inflorescence: this type of leaf arrangement is ***cauline*** (example is *Phragmites australis*)
- Actually a bract, not a leaf: three thin bracts just under the flower (or inflorescence) is common in the family Cyperaceae (example is *Bolboschoenus*)
- A long blade, attached to the rhizome: leaves grow from the base, so the oldest part of the leaf blade is the tip: this type of leaf arrangement is ***basal*** (example is *Typha* spp.)
- Reduced to a short sheath around the culm: common in two families, Juncaceae and Cyperaceae (example is Giant Rush *Juncus ingens*)



The lifespan of leaves for *Typha* and *Phragmites* is quite short, less than a year: most die in late summer-early autumn. They may die earlier in response to extreme desiccation.

Leaves and shoots of *Juncus* live longer than a year.

2: Growth

Annual Growth & Biomass

These two plots show changes through the year in biomass of Broad-leafed Cumbungi and *Phragmites*, harvested from beside Mirrool Creek, near Griffith, NSW.

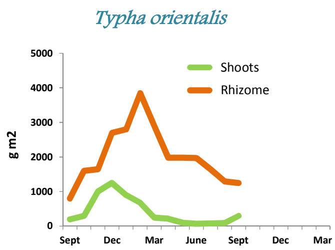
The general pattern is broadly the same for both *Typha* and *Phragmites*:

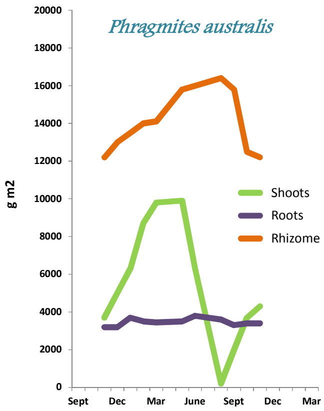
- Aboveground biomass (shoots: green) peaks in summer, then falls as shoots die-off.
- Belowground biomass (burnt orange: rhizome) peaks later.
- Belowground biomass is much bigger than aboveground biomass.
- Biomass of roots is much the same all year, with no seasonal pattern: the roots just keep on being produced and dying off.

On this creek, *Phragmites* has a much higher biomass than *Typha*. Peak biomass for *Typha* shoots is about 1500 g m^2, whereas peak biomass for *Phragmites* shoots (live) is 9890g m^2.

These data sets are quite special. There are very few Australian data sets showing year-round biomass for wetland plants.

Annual Growth & Biomass





These two plots are on the same scale.

Note that 1000 g m^2 is equivalent to 10 tonnes ha

The plots are for live material only.

Stands of Phragmites also carry a lot of standing dead material.

Conceptual Model of Annual Growth

Think of a conceptual model as a simplified description.

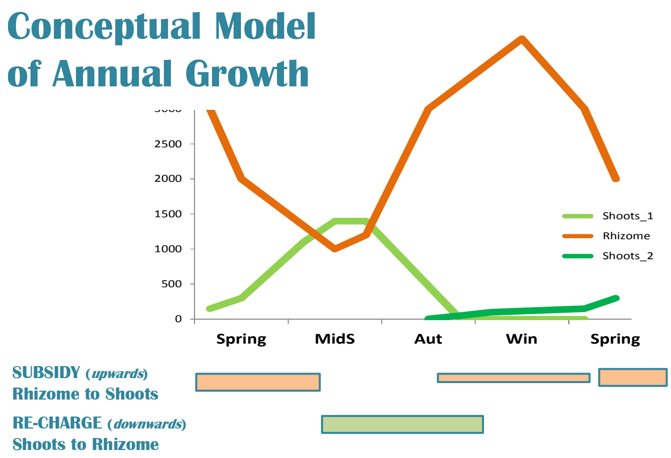
The aboveground parts and the belowground parts have special and different roles, shown in italics:

- Aboveground biomass is mostly leaves. The leaves and the stem photosynthesise (*capture energy from the sun*). Other aboveground parts are the flower and seeds (*sexual reproduction*).
- Belowground biomass is mostly rhizome. The rhizome stores energy in the form of starch (*reserve*). Other belowground parts are roots, and buds on the rhizome (*vegetative reproduction, clonal growth*).

The aboveground and belowground parts are connected by the movement of stored energy, as subsidy and recharge. This happens at different times of the year.

Subsidy: The very rapid growth of *Typha* and *Phragmites* in spring is due to mobilisation of energy in rhizome and using it for shoot growth above ground (orange bar in diagram: also happens a little in autumn in warm areas when next generation of shoots appear). This means the shoots can grow much faster than if they were relying on photosynthesis alone. This subsidy helps *Typha* and *Phragmites* to crowd out (by shading) other plants. It helps the second generation of shoots over winter as well.

Re-charge: Once the shoots reach peak biomass, they flower, and then start to send captured energy back down to the rhizome, building up the starch reserves (green bar in rhizome). This means the rhizome biomass increases below ground while the first generation of shoots is dying off above ground.



Shoots of Typha and Phragmites live for less than a year.

A new canopy is formed each year with a new population of shoots. Sometimes (in areas with warm climate, the first and second generations of shoots overlap.

But the rhizome lives much longer than 1 year (see next section)

Knowing which way energy is being moved around inside the plant is helpful for planning the timing of control measures.

3. The Rhizome

Introducing the rhizome

The rhizome is chunky, and anywhere between 20 and 70 cm underground.

The example (right) is for Tall Spike Rush *Eleocharis sphacelata*. It shows the rhizome after being washed clean of mud, and after the roots and shoots have been trimmed off.

Tall Spike Rush is not known to be a problem species.

Rhizome

DEFINITION
Stem growing +/- horizontally below ground

APPEARANCE
Thick, Woody. Short & fat – Long & thin

LONGEVITY
About 6 years for *Typha* ? (in saturated soils)
As much as 10-15 years for *Phragmites* ? (in dry muds)

GROWTH BEHAVIOUR
End forms tip, grows upwards, forms a shoot (culm) and flowers

FUNCTIONS
Starch Storage
Stabilisation & Anchorage (with roots)
Bud Reservoir
Resistance
Vegetative spread
Competitive

How a rhizome grows: Diagram

The rhizome grows from tiny buds, near the tip.

It grows laterally in the ground, and then develops a shoot at the tip.

If the species develops more than one tiny bud, then it grows by a distinctive branching pattern (see right).

As the rhizome continues to grow, and to develop new parts, the older parts die off (shown by the dotted line: right). When this happens, the newer bits of rhizome are no longer connected to each other.

If the rhizomes continue to grow and expand, then eventually the plant will cover a large area. It may be only one genetic individual.

Rhizome Growth (schematic)

Key Words
Modular growth (units repeat themselves)
Units of rhizome + shoot called ***ramets***
Clonal growth (each unit is genetic repeat of parent)
Vegetative reproduction
This is a simple growth pattern

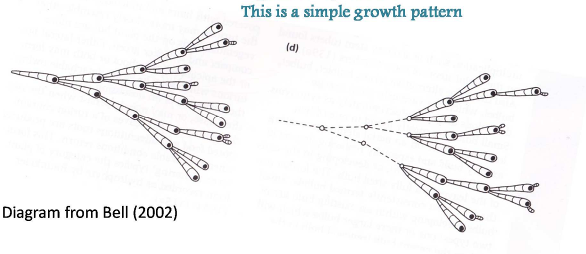


Diagram from Bell (2002)

This diagram is from a book on plant morphology (Bell 2002)

How a rhizome grows: Drawing

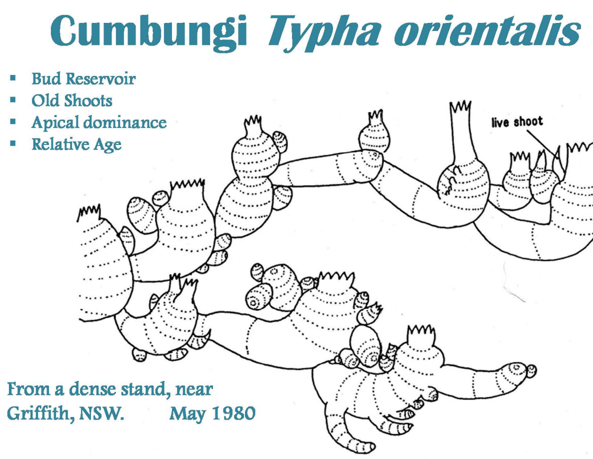
Drawing of a rhizome of Broad-leafed Cumbungi, dug up while sampling at Griffith, NSW. The rhizome was washed clean of mud, the shoots and roots were trimmed off, leaving the chunky rhizome.

With *Typha*, each rhizome crown carries a row of buds (up to 60) on each side: this is the *bud reservoir*. Mostly these are too small to see. The ones in the diagram have swollen, have begun to grow, but not advanced.

The living shoot prevents the buds from growing: this is *apical dominance*. This suppression ceases when a living shoot is lost (cut, grazed, burnt, or otherwise removed). Although many buds may begin to grow, only one or two eventually succeed.

This is why strategies such as burning or slashing or grazing the aboveground plant results in denser shoots later.

The oldest part of this rhizome is on the left: the youngest parts are on the right. This rhizome has had six growth pulses (along upper branch), making the oldest bit probably six years old.



Harvesting Tall Spike Rush: Pictorial

Professor Takashi Asaeda (of Japan) investigated growth of Tall Spike Rush at two sites: Rowe Lagoon, near Goulburn NSW (cool, tablelands) and near Ourimbah, Newcastle NSW (warm, coastal). This is the principal work on Tall Spike Rush in Australia. This project is shown in photographs numbered [1] to [4] (shown next page).

[1] Harvesting, especially belowground material, is heavy work. A team is handy to dig up a quadrat, bag it, and carry it out of the wetland.

[2] and [3] Cleaning and sorting the harvested material is labour intensive. A team effort is needed to wash the harvested material free of mud, then cut it up and sort into live and dead material, and into shoots, roots, rhizome, and sometimes even different ages.

[4] Measurements such as rhizome diameter, shoot heights may be recorded.

As well as working on Tall Spike Rush, Professor Takashi Asaeda developed simulation models describing growth of *Typha* and *Phragmites.* These growth models, once validated, can be used to explore how a plant responds to different environmental conditions, and to harvesting.

Tall Spike Rush
Eleocharis sphacelata

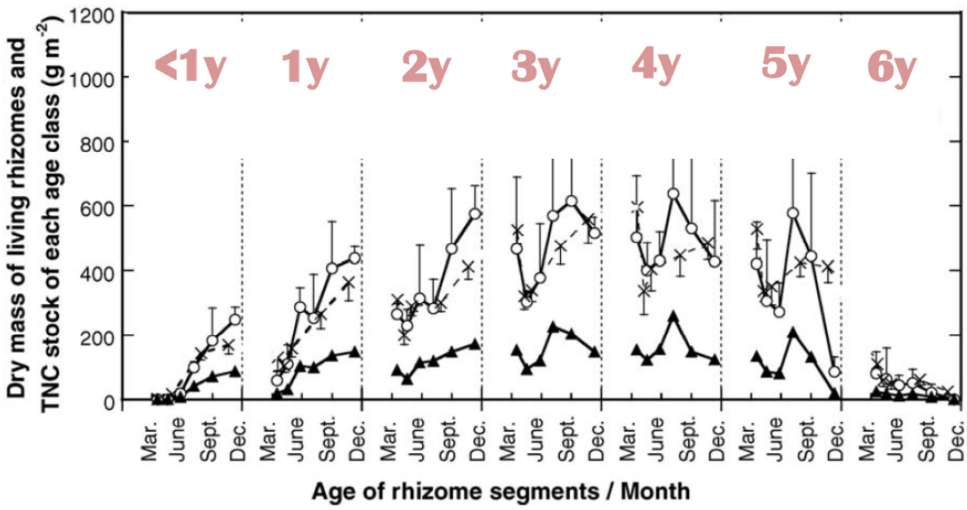
Rhizome: Function and Age

Rhizome function and biomass changes as the rhizome ages. This is shown (below) for *Phragmites australis*. Each panel is a rhizome of a particular age, from less than a year, to 6 years old.

The upper lines are biomass: this increased during the year (within a panel), and increased up to years 4 and 5. At this site, the 6-year old rhizomes were disintegrating and rotting and very low biomass.

The lower darker line is the concentration of starch in the rhizome. This shows the same pattern as biomass, of generally increasing with age but becoming ineffective by the end of year 5.

In Years 3, 4 and early 5, biomass was high, and starch concentration also high; making these important years in plant resilience.

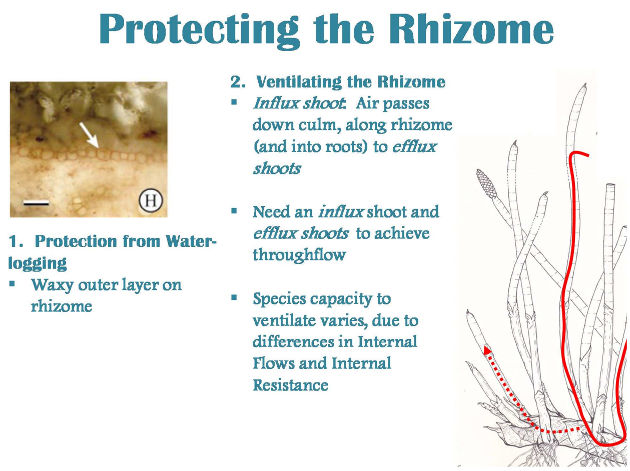


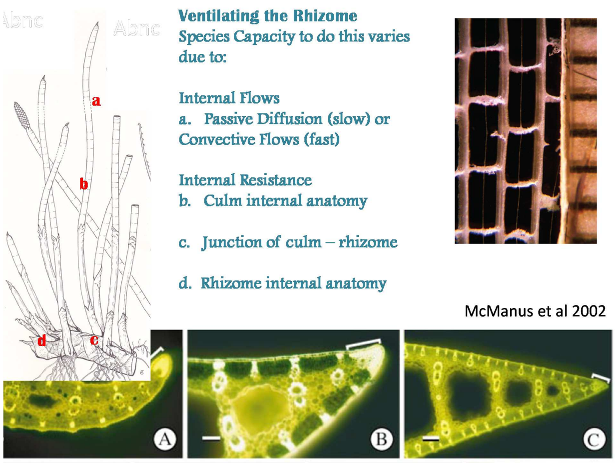
This diagram is Figure 3 in Asaeda et al (2006).

Protecting the Rhizome

Wetland soils are difficult for plants. The substrate is often anoxic (without oxygen, which plant cells need). Plus anoxic soils can have naturally-occurring chemical in forms that are toxic to rhizome and roots.

Tall Spike Rush protects itself by having a special protective layer around the rhizome (see shiny brown photo, previous page) and by moving air from the atmosphere down the shoot and into the rhizome and roots (red line, right), then back out of an old shoot.





In tall emergent macrophytes, the shoot tissue is quite porous, with lots of airspaces (see left). This allows air to travel through the shoot.

The plant does have places where its internal anatomy offers some resistance to air flow (see left).

Images of cross-sections through Typha shoot (top right) are from Witztum and Rayne (2014), and through different parts of Typha (bottom line) are from McManus et al (2002).

Effective Ventilation:
an adaptation allowing growth in water

Flow rates = HIGH
Eleocharis sphacelata
Phragmites australis
Typha domingensis
Typha orientalis

Flow rates = LOW
Baumea arthrophylla
Baumea articulata
Bolboschoenus medianus
Cyperus eragrostis
Cyperus involucratus
Juncus ingens
Schoenoplectus validus
Typha latifolia

Flow rates = ABSENT
Eleocharis acuta

Published research by:
Sorrell and Hawes 2010
Brix et al 1992
Vretare and Weisner 2000

Differences between species

Ventilation refers to the capacity of an emergent macrophyte to move air into its rhizome. This is a mixture of physiological adaptations, and internal anatomical features. The movement of air downwards can be measured.

There is an enormous difference between emergent macrophytes in how well they do this.

The real stars at this are the native *Typha* spp, *Phragmites australis*, and Tall Spike Rush *Eleocharis sphacelata*. They can achieve high internal air flow rates.

The introduced *Typha* has low internal flow rates.

And in some species, no flow rate can be detected.

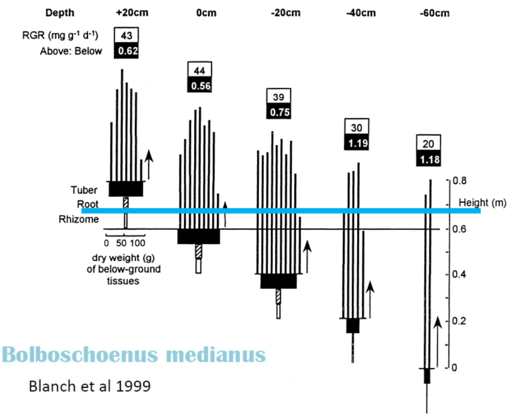
Growth implications

The capacity to ventilate the rhizome is a major factor in determining how deep a plant can grow.

As water gets deeper, plants re-distribute their biomass (taller and fewer shoots) so as to keep shoots in the air.

This was nicely described for *Bolboschoenus medianus* (right).

Resource allocation v depth



Bolboschoenus medianus

Blanch et al 1999

4. Using Water Regime to manage *Typha* and *Phragmites*

Comparison of *Typha* and *Phragmites*

Characteristics in Common

Highly Productive: Large biomass. Have leaves.

Annual Canopy: Not evergreen. Overlapping generations of shoots.

Rhizome Ventilation : High internal air-flow rates. Deep water species.

Invasive. Competitive. Native

Seedling: Rhizome develops while seedling still young.

Resistance & Resilience: Role of rhizome

Differences

Density: Culm density much lower in *Typha* (5-10 per m^2)can be very dense in *Phragmites* (200-400 per m^2)

Phenology : Maximum biomass and flowering is earlier in *Typha* (Dec-Jan) than *Phragmites* (Jan-Feb)

Leaf arrangement: Basal, strap-like for *Typha* but is flag-like, cauline in *Phragmites*

Reproduction: Numbers of seeds much higher for *Typha* (300,000+ per inflorescence), higher viability, readily-dispersed

Habitat: *Phragmites* more likely in a riverine habitat than *Typha*

Summary

From a manager's view, there is not a lot of difference between managing *Typha* and *Phragmites*: they occupy a very similar water regime niche.

Principal differences are:

- Timing of flowering and maximum biomass (*Phragmites* is later):
- Invasion and colonisation from seeds (likely for *Typha*; unlikely to rare for *Phragmites*)
- Drought resistance (*Phragmites* lasts longer: its rhizome lives longer*)*
- Flowing water habitat (*Phragmites* is more likely: *Typha* not so resistant to floods)

Can water regime be used: to increase vigour ? to reduce vigour ? to eliminate whole stands ?

Yes, vigour can be increased by providing a favourable water regime; and if plants are already very vigorous, then they can be easily maintained high.

Favourable water regime: A favourable water regime (blue part of table on next page) produces tall shoots and vigorous stands, and builds up rhizome storage underground.

Repeatedly providing a favourable water regime will encourage *Typha* and *Phragmites* to build up their resistance and resilience. The rhizome acts as a buffer to change.

Yes, vigour can be reduced, by providing unfavourable conditions.

Unfavourable water regime: An unfavourable water regime is one with shorter duration of flooding and/or longer dry intervals, and less frequency of flooding, than for favourable. Reducing vigour after sustained favourable conditions will require a few years of unfavourable conditions (shown as Tolerances: red-brown text in table below).

Effectively, this is a sustained shift in management.

Yes, stands can be eliminated, by providing conditions that discourage growth, and put the plant under stress.

Elimination: Deliberate elimination (by manipulating water regime only) is hard to achieve. It requires single-minded application, and must be sustained over a few to several years.

There are two ways to stress these plants using water regime. One is to make conditions that are too wet, and the other is to make conditions that are too dry.

- For conditions to be too wet for *Typha* and *Phragmites*, a manager must deliver a water regime that floods deeply (at least 1 m or 1.25 m) for several months in the growing season (preferably spring-autumn inclusive) and repeat this for 2-3 years. This requires a lot of water so is feasible only in special circumstances.
- For conditions to be too dry for *Typha* and *Phragmites*, a manager must have tight control over inflows (preferably none !), for several consecutive years. The intent is to encourage rhizomes to die off, and to discourage vigorous aboveground growth that would re-charge the rhizome (shown in red-brown text in table below). Extending the duration of the dry interval to last several years can be hard to achieve, if the target wetland receives natural flow and run-off.

The manager needs to be mindful of risks, such as accidentally encouraging germination and establishment. If flooding for a short duration or to shallow depths, then this should be carefully timed as this could provide ideal conditions for seedlings to establish, especially of *Typha*. It is important to avoid encouraging any shoot growth, as this could help maintain the rhizome.

Water Regime and Vigour

	Typha	*Phragmites*
Frequency	Annual; up to every 2-3 years	Annual; up to every 2-3 years
Depth	Not critical Grows vigorously in 30 to 150 cm	Not critical Grows well in 10 to 100 cm
Duration	From 8 to 12 months Grows well in less (6 months) if timed July-December	From 8 to 12 months Grows well in less (6 months) if timed August-January
Timing (wet)	Start Autumn-Winter	Spring-Autumn
Timing (dry)	Late Summer-Autumn	~~Autumn-early Winter
Tolerances	Re-establishes its canopy quite well after 2 years dry. Can regrow from 5 years dry but is much less vigorous. Drawdown (dry soil) lasting 3 years will reduce vigour.	Re-establishes its canopy quite well after 2 (even 3 ?) years dry. Can regrow from 7 years dry but is much less vigorous. Drawdown (dry soil) of 4 years (maybe 3 ?) will reduce vigour.
Elimination	Elimination difficult to achieve. Requires consecutive years dry (more than 5, as much as 7).	Elimination not practicable. Stems die and breakdown, but rhizomes last several years

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Reference for general use

Descriptions of 17 wetland plant species, including *Typha* spp and *Phragmites australis*, their life history, ecology and water regime:

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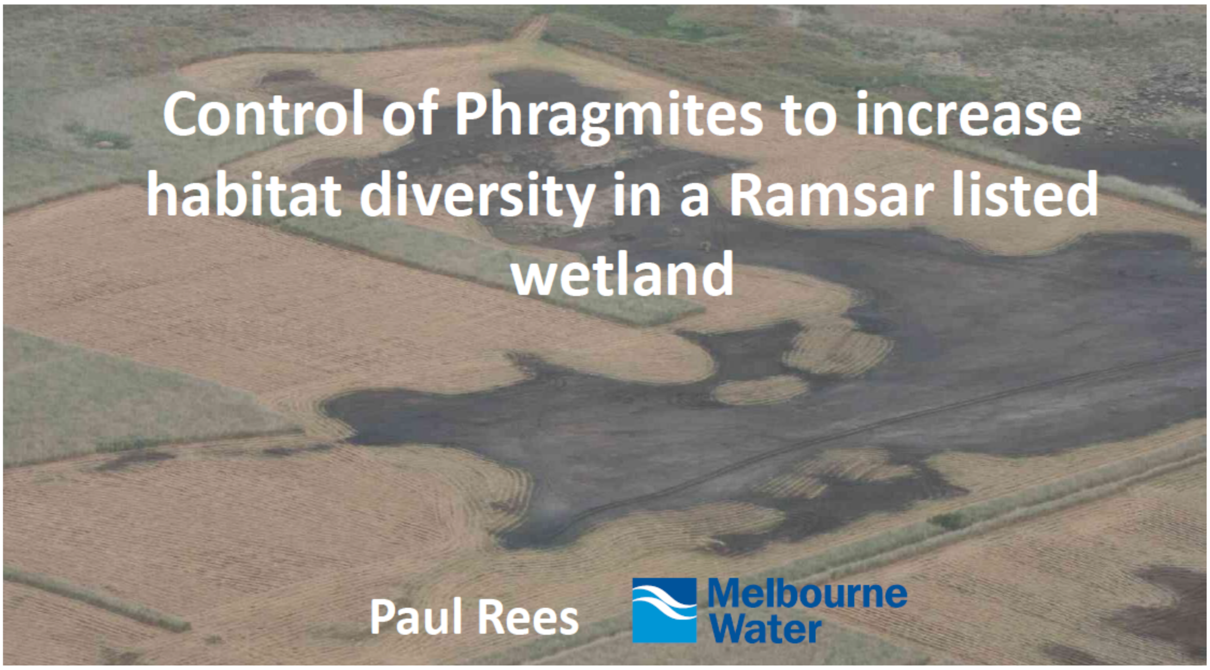
http://www.nwc.gov.au/__data/assets/pdf_file/0007/11230/Wetlands_full_document.pdf

The file can be downloaded as a full document with all species (17 MB) or in parts.



1: Context and Historical Perspective

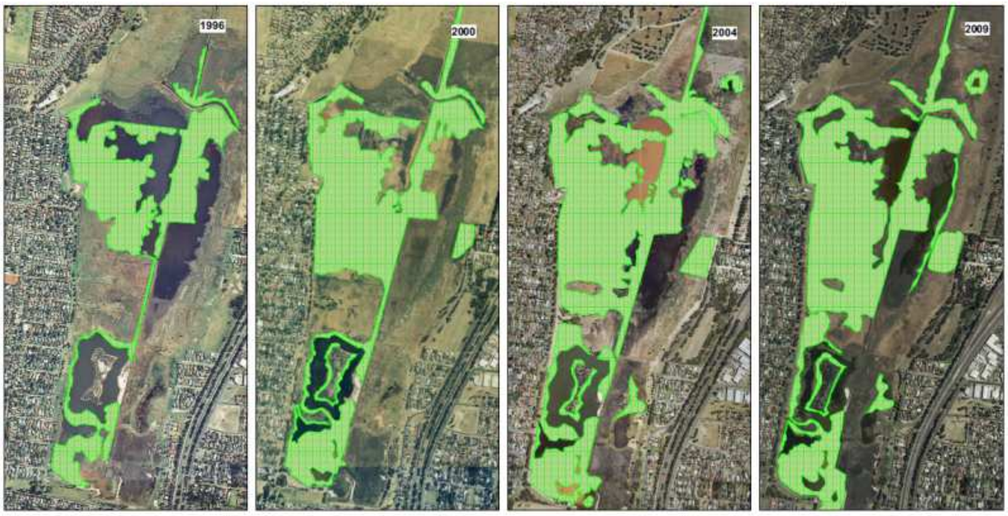
Background

Changes to the hydrology of wetlands, increases in nutrients entering the wetlands, and the recent drought have combined to allow significant expansion of Tall Marsh, a wetland Ecological Vegetation Class (EVC) characterised by tall emergent macrophytes, in many wetlands across Victoria.

This expansion is a particular problem at two Ramsar wetlands for which Melbourne Water is responsible, Seaford and Edithvale, as it reduces other habitats which are important for waterbirds.

Melbourne Water has found that understanding recent and historic changes in the extent of Tall Marsh provides a valuable understanding of the wetlands, and provides a realistic context for management decisions.

Seaford: Below is a recent time series (aerial photography from 1996, 2000, 2004 and 2009) showing how Tall Marsh (green shading) has increased over 13 years at Seaford. Map taken from Australian Ecosystems (2011).



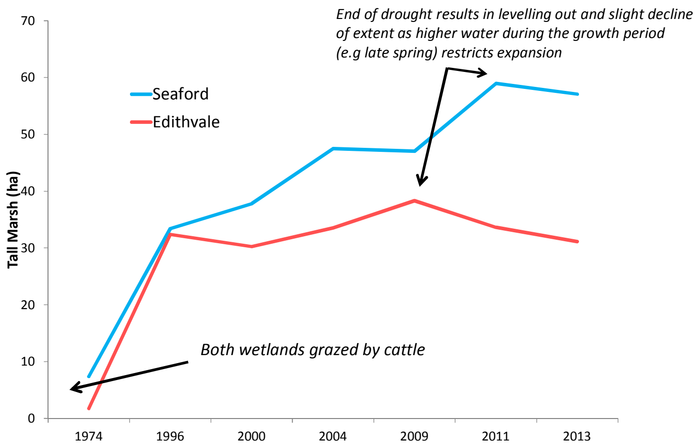
Edithvale: Below is a recent time series of aerial photographs (2000, 2004 and 2009) showing how Tall Marsh, which is here dominated by *Phragmites* and *Typha* (green shading), has increased in extent over nine years at Edithvale Wetlands. Map taken from Australian Ecosystems (2011).

Historical Perspective

Seaford and Edithvale show broadly similar patterns through recent time (right).

Tall Marsh was only a small area in mid 1970s, then increased, and by 1996 covered more than 30 ha.

Since 1996, Tall Marsh has continued to expand at Seaford, while remaining between 30-40 ha at Edithvale.



Factors believed to have influenced these patterns are:

- End of Millenium Drought: Tall Marsh expansion slows, believed to be due to high water in spring limiting vegetative expansion
- Mid-1970s: wetlands were grazed by cattle which may have suppressed growth and removed biomass.
- 1850s to 1970s: grazing was extensive and would have kept *Phragmites* short.

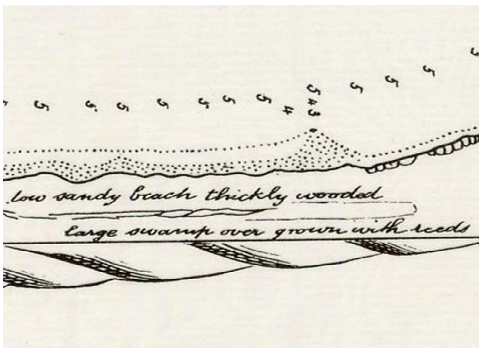
Historical maps can confirm the longevity of a wetland.

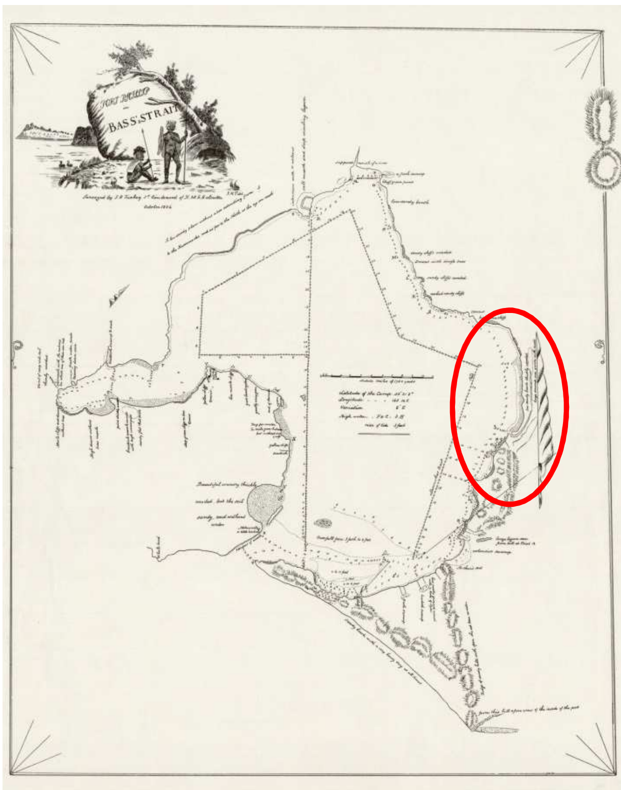
This 1804 map of Port Phillip Bay and Surrounds shows a large wetland on its eastern shore (red oval), consistent with the current location of the Edithvale-Seaford wetlands.

The text inside the red oval (see detail below) reads:

Low sandy beach thickly wooded

Large swamp over grown with reeds





2: Balancing Requirements

Conflicting Habitat Requirements

The Tall Marsh at Seaford and Edithvale the wetlands is considered regionally significant, as one of the last remaining large stands and it is important habitat for threatened species such as Australasian Bittern and other reed-dependent birds.

However within these wetlands, Tall Marsh is expanding into mudflat areas (and Aquatic Herbland) which are critically important for migratory birds, such as Sharp-tailed Sandpipers. Without continually exposing mudflat over spring/summer the birds will have nowhere to forage.

Targets

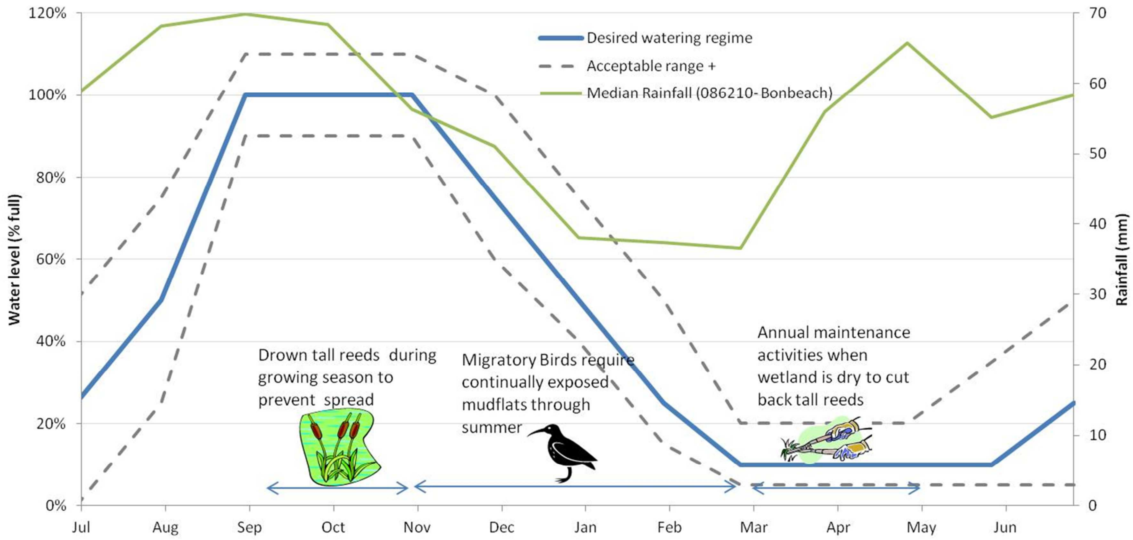
An expert workshop identified the following target areas (proportions) for the wetlands, based on trying to balance the values.

- 34 ha of Tall Marsh is an appropriate target for Seaford (currently 57 ha)
- 24 ha of Tall Marsh is an appropriate target for Edithvale (currently 31 ha)

These target areas are similar to the extent of Tall Marsh (*Phragmites*) in about 1996 (see above).

To achieve this target, the workshop recommendation was to slash and spray (Jan-April) after flowering has commenced and before seed set to ensure that culms are cut before the plants begin to senesce.

The workshop identified an '*ideal water regime*' for Edithvale and Seaford wetlands, that would meet management objectives of constraining *Phragmites* expansion, and allowing access for active management. This is shown below as a diagram.

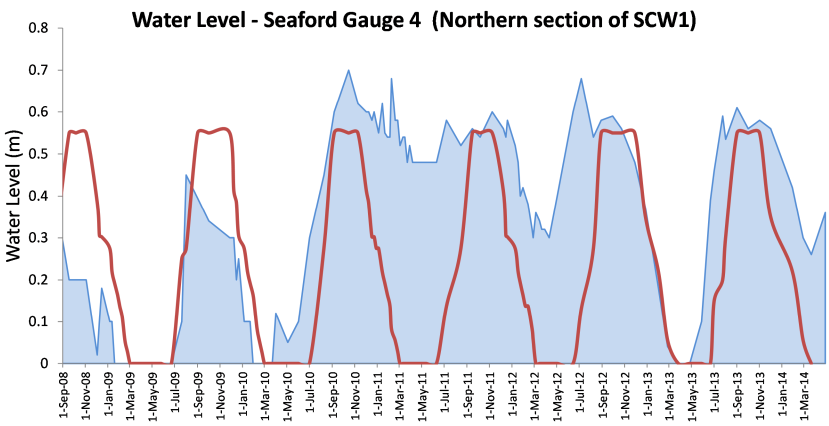


For interest, the ideal water regime can be compared with very recent (last 6 years) water regime history at Seaford, and recent (last 25 years) water regime at Edithvale.

Seaford

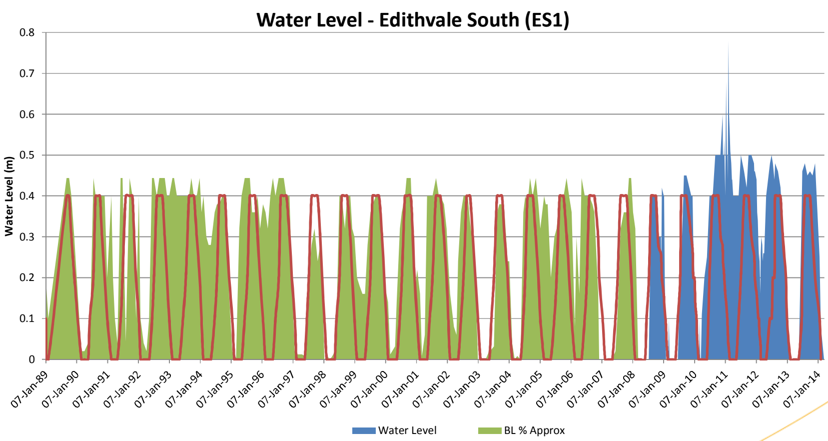
The time series for Seaford Gauge 4 shows the ideal water regime (below: red) compared with actual record for Seaford Gauge 4 over the last six years (Sept 2008 to March 2014) in blue. The last six years comprise:

- o two drought years when flooding was shallower than ideal, but about the expected duration:
- o two-three years when conditions were very wet, and flooding was more extensive, deeper and lasted longer than the ideal;
- o one year when flooding was close to the ideal in terms of depth but started slightly earlier and did not dry out.



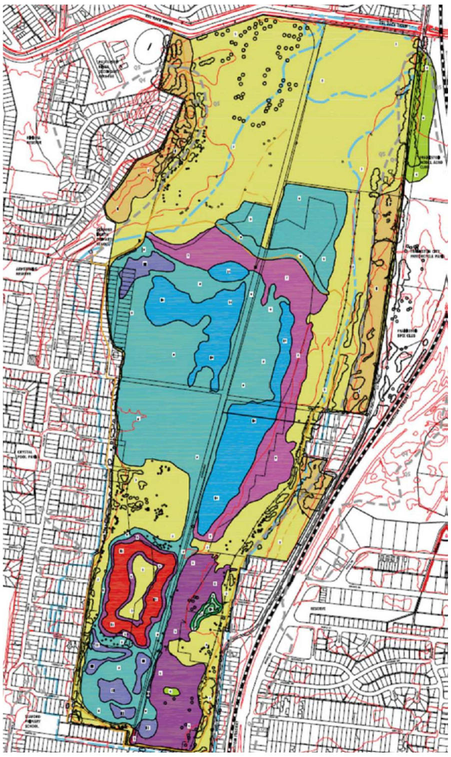
Edithvale

Extending this perspective even further back in time is possible at Edithvale, by using two data sources: staff gauge readings by Melbourne Water (blue), and visual estimates made as part of long-term bird monitoring (green) by BirdLife Australia.



3: Study Area: Wetland Vegetation

Mapping for Seaford (left) and Edithvale (right) shows the vegetation types, and is a reminder of the proximity of residential urban areas.



4: Slashing to Control *Phragmites*: A Learning Process

Slashing was selected as the method for controlling *Phragmites* as being the most appropriate and least risky for these two wetlands. Site-specific considerations were: both sites are within urban areas; and acid sulfate soils underly the wetlands.

4a: Seaford Wetland, 2007 and 2008

In 2007-2008, slashing was used to control the extent of *Phragmites* at Seaford Wetland.

The Plan

Ecological Purpose: to increase the area of mudflat and so increase overall habitat diversity for waterbirds.

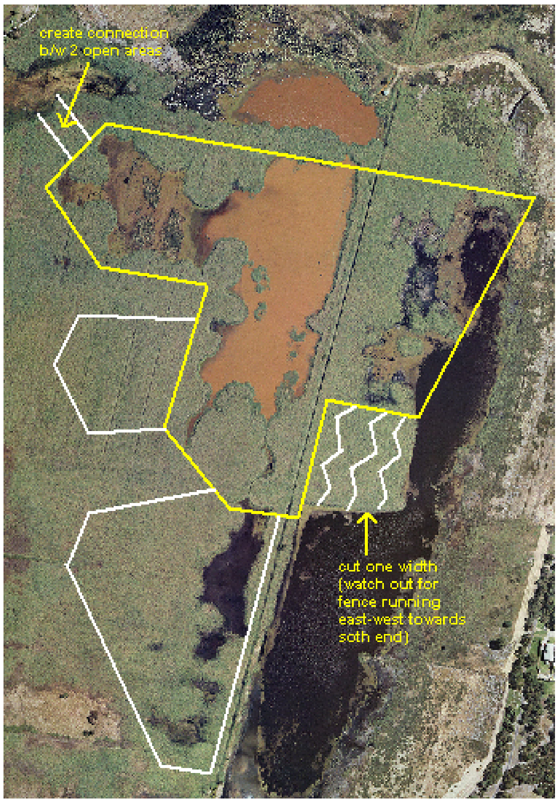
Timing: Slashing was done in autumn-winter, in consecutive years: in March 2007, then in May-June 2008.

Methods: Slashing only. Done using a multi-terrain vehicle (a forestry groomer).

No follow-up herbicides.

No follow-up flooding although this would have been desirable (drought years: infrastructure constraints meant water could not delivered).

Design: Diagram (right) shows the plan for slashing: area around a large waterbody (inside yellow line and white line); a narrow corridor from large waterbody to small waterbody (top left); three sinuous lines to open up a patch (centre right).



Implementation

Area = 19 ha in 2007. Map shows slashed area (yellow-shaded area). Right is a photograph.

Result

Recovery: Photo (right) taken one month after slashing, in April 2007. Slashed trash is still on ground. *Phragmites* shoots have re-grown, several centimeters.

Conclusion

Slashing with no follow-up is not enough: possibly the slashing was too early.

4b: Edithvale Wetland, 2013 and 2014

Management of *Phragmites* at Edithvale wetland was able to build on the experience at Seaford a few years earlier, and in 2013-2014, slashing plus follow-up treatments was used to control *Phragmites*.

Ecological Purpose: to increase habitat diversity, and reduce *Phragmites* density.

Timing: Slashing was done in autumn: in March 2013 (2.6 ha) and in March 2014 (12.6 ha).

Methods: Slashing was done using a multi-terrain vehicle (a forestry groomer).

Follow-up treatments were:

- Wick-wiping with Round-up Bioactive (six weeks after slashing)
- Flooding started two months after slashing, in May 2013. Flooding duration was long (about 9 months) to February 2014.

A Forestry Groomer (right) in action at Edithvale Wetland. Although fairly heavy, the tracks mean it does not sink. A rake can be attached at the front to move trash.

Before: January 2013

Photo (right) shows part of Edithvale wetland in January 2013, prior to treatment. The *Phragmites* (bright green) surrounds an open area of mudflat, with a residual pool of water.

After: March 2013

Photo (right) shows same area of Edithvale wetland in March 2013, after slashing and wick-wiping. The extensive trash of slashed *Phragmites* (pale brown) is evident.

Dealing with the Trash

Close up of slashed *Phragmites* (and fence post !). This is expensive to remove but left in place can shade-out next generation of plants. So, subsequent to slashing and before flooding, while ground still firm, the trash was raked up into piles (evident in the next photograph).

Some of the trash was re-cycled by swans that used it for nesting.

Raked piles are evident as pale dots (right: October 2013) and amongst the Water Ribbons (below: December 2013).

After: December 2013

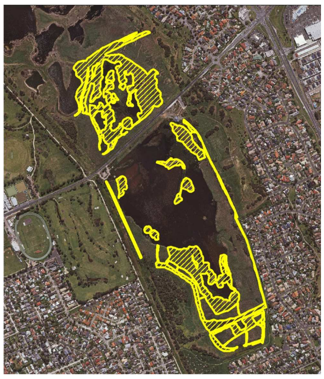
The view on-ground (right) after slashing and wick-wiping, raking trash into piles, and flooding over winter, showing extensive growth of Water Ribbons *Triglochin* sp . However, some areas of *Phragmites* re-growth were also apparent (green shaded area, below).

Slashing: second round in March 2014

Total area slashed in March 2014 = 12.6 ha

Second round of slashing was mostly in a different part of Edithvale wetland but did include some of the identified re-growth from the first round.

Diagram (right) shows shaded area (yellow) scheduled for slashing.



5: Monitoring and Evaluation

Monitoring Program

Melbourne Water is working with University of Melbourne.

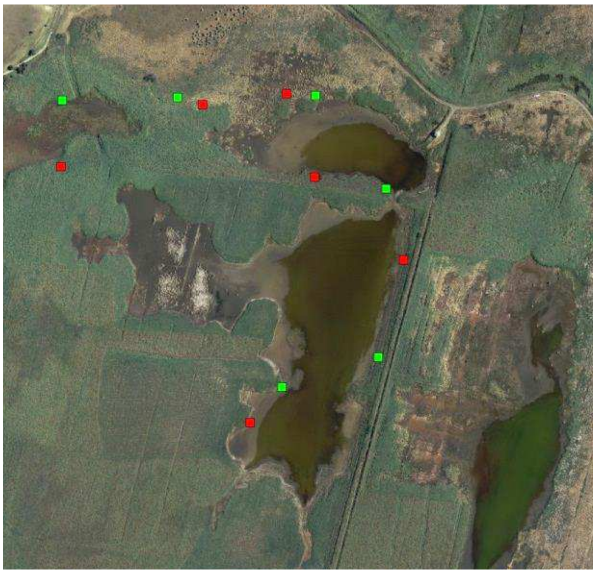
Aim: To evaluate the effectiveness of slashing (and no wick-spraying) on *Phragmites* that gets flooded over winter

Timing: Established in June 2013. To be re-read annually (funding permitted).

Design: Six paired quadrats (one slashed, one not slashed) (red and green squares on right)

Location: Seaford Wetland

Response Variables: diversity, cover



Findings of Monitoring Program

Monitoring program is only recently established. Baseline data recorded but no results as yet.

Observations show considerable differences in post-slashing recovery of *Phragmites* depending on location (elevation) within wetland.

One year after setting up the experiment, *Phragmites* re-growth at 'higher' elevations (above 0.5 m AHD: on left) is much greater than *Phragmites* at 'lower' elevations (below 0.5 m AHD: on right)).

Appraisal

Phragmites control has had a significant effect on type of vegetation present (for example: extensive Water Ribbons *Triglochin* and swards of *Bolboschoenus*) and more open areas (see above for Edithvale Wetland).

It has also had a dramatic effect on the avifauna.

Edithvale South and Sharp-tailed Sandpipers

Over 3500 Sharp-tailed Sandpipers recorded at Edithvale South in February 2014.

This is over 2% of the entire world population (166,000) of this species, and was one of the highest records for Edithvale Wetlands in several years.

Bird Life Australia has been monitoring birds monthly at Edithvale South wetlands since 1989. Andrew Silcocks of BirdLife Australia volunteered these very positive comments on the increased number of wetland birds, and the occurrence of two threatened species, and the efforts of Melbourne Water to manage this site.

"*Results from the monthly bird surveys have revealed a significant increase in waterbirds using the wetland since it filled, most notably in and around the area where the Phragmites has been cut.*

Using the southern wetland at the moment are good numbers of Black Swans (up to 180), various duck species (six species, up to 120 in total), Purple Swamphens (up to 140) and Black-winged Stilt (up to 7). In addition, two threatened species, Australasian Bittern and Magpie Goose have been regularly seen in this area.

While the Phragmites does have an important role to play for birds in providing breeding sites and shelter, its tall dense habit makes it largely impenetrable for wildlife to feed within it. Being a very invasive species, it can rapidly spread over wetlands at the expense of other water plants. A rotational program of Phragmites cutting, and in some areas Typha, will enhance the wetland values and should be maintained.

Please could you pass on our thanks to the team for carrying out this active management at the site."

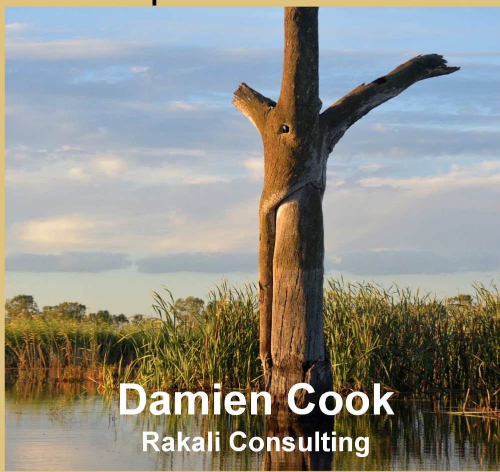
6. References

Australian Ecosystems (2011). *Edithvale-Seaford Wetlands – Mapping the extent and distribution of over-abundant native and exotic species*. Unpublished report prepared for Melbourne Water.

Sinclair Knight Merz (2012). *Environmental water requirements and associated capital works for the Edithvale-Seaford Wetlands.* Unpublished Report prepared for Melbourne Water.

Thompson Berrill Landscape Design & Australian Ecosystems (2004). *Edithvale-Seaford Wetlands Revegetation Prescriptions.* Unpublished report prepared for Melbourne Water and Frankston City Council.

Invasion of *Phragmites australis* & native *Typha* spp. into historically intermittently inundated wetland plant communities



1: Introduction

Using a wetland as water storage or as part of a water delivery system, which is common through northern Victoria, causes major hydrological changes to that wetland. In turn, this leads to changes in wetland vegetation, such as: the death of 1000s of hectares of River Red Gum-dominated communities; changes in the composition of understorey communities; and invasion by *Typha* species and *Phragmites australis* (henceforward referred to *Typha* and *Phragmites*). The net result is a decrease in the diversity and cover of other wetland plants, and this affects wetland values.

This paper explores this in more detail, using three wetlands from northern Victoria as case studies. It makes specific suggestions on managing *Typha* and *Phragmites* by changing the water regime.

Case Studies: The three wetlands are McDonald Swamp, Johnson Swamp and Hird Swamp. Johnson and Hird are Ramsar sites, being part of the Kerang Lakes Ramsar site. The wetlands are in the Murray Fans and Victorian Riverina bioregions.

2: Wetland Vegetation: *Before* and *Current*

When change is so extensive and so widespread, it can be hard to appreciate what the vegetation was like before wetland hydrology was altered. This section is a reminder of the richness and diversity of wetland vegetation before utilisation changed the water regime for two vegetation types important at McDonalds, Johnson and Hird Swamps: Intermittent Swampy Woodland, and Lignum Swampy Woodland.

2a: Intermittent Swampy Woodland

The preferred water regime for this EVC is: *Episodic or intermittent inundation by freshwater, from 30 to 100 cm deep, for 1 to 6 months, in 3 to 7 years out of every 10*.

Before: Before hydrological changes, the deepest part of all these case study wetlands would have supported an open canopy of River Red Gums, known as Intermittent Swampy Woodland.

Examples of Intermittent Swampy Woodland in good condition are quite rare: the example (right) is Scottie's billabong.

The understorey of Intermittent Swamp Woodland varies according to depth, duration and frequency of inundation.

When inundated, deeper areas may support submerged and floating-leaved aquatic herbs, such as Wavy Marshwort (below left), and Blunt Pondweed with *Azolla* (below right).

When inundated, shallower areas may support herbs such as Common Nardoo (below left) and Spiny Flat Sedge (below right). Occasionally *Phragmites* may be present, but only as a minor component.

As the inundation phase ends and begins to dry out, different species germinate and establish on the drying mud, examples below (Left to Right): Old Man Weed, Hoary Scurf-pea; Native Liquorice.



Current: Most of the large, old River Red Gums are now dead, drowned because of prolonged flooding. This was the result of excess irrigation water being dumped into the wetlands. Changes in the duration and frequency of flooding have also changed the understorey vegetation.

The cover and diversity of understorey aquatic herbs is now relatively low, whereas invasives favoured by a wetter water regime, such as *Typha* and *Phragmites* are abundant. When the wetlands dry out, weed cover can be very high, and the diversity and cover of indigenous species relatively low.

2b: Lignum Swampy Woodland

The preferred water regime for this EVC is: *Episodic or intermittent inundation by freshwater, from 10 to 50 cm deep, for 1 to 3 months, in 3 to 7 years out of every 10.*

Before: Before hydrological changes, wetlands such as Hird and Johnson Swamps would have had a fringe of Black Box and Lignum dominated vegetation, known as Lignum Swampy Woodland.

The example (right) is from the southern end of Hird Swamp.

Current: Prolonged water-logging and saline groundwater tables which have risen close to the soil surface have caused the death of many Black Box trees and facilitate the invasion of halophytic plants such as Black-seeded Glasswort into vegetation that was previously characterised by freshwater species.

Despite such changes, there are still small areas of Lignum Swampy Woodland that are relatively intact at both Hird and Johnson Swamps. These have a healthy tree canopy and shrub-layer, and a diverse understorey when inundated.

3. Changes to the Wetlands

The hydrological changes to the three wetlands are outlined here. Vegetation maps are taken from Cook et al (2014).

3a. McDonald Swamp

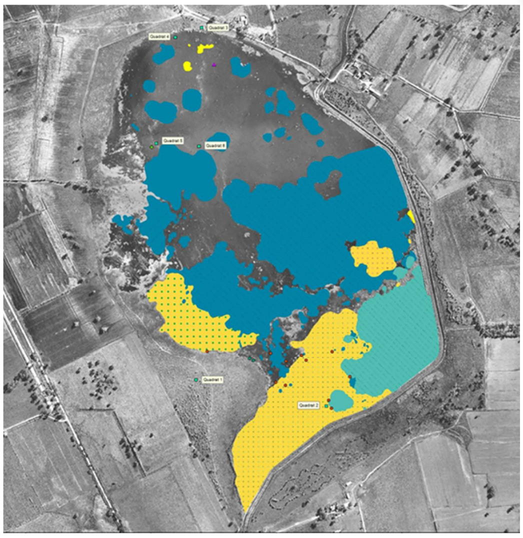
Aerial photograph showing changes to drainage patterns at McDonald Swamp between 1945 (left) and 2004 (right). Construction of a drain through the south-east part of the swamp and along its eastern edge has had a significant impact on vegetation.

Before hydrological changes, the centre of the wetland would have been covered by Intermittent Swampy Woodland (see previous section).

Contemporary Vegetation: The map (right) shows the distribution of *Phragmites* and *Typha spp*. Combined, these cover 38% of the Swamp. East of the drain, there is no *Typha*, and only a small area of *Phragmites*.

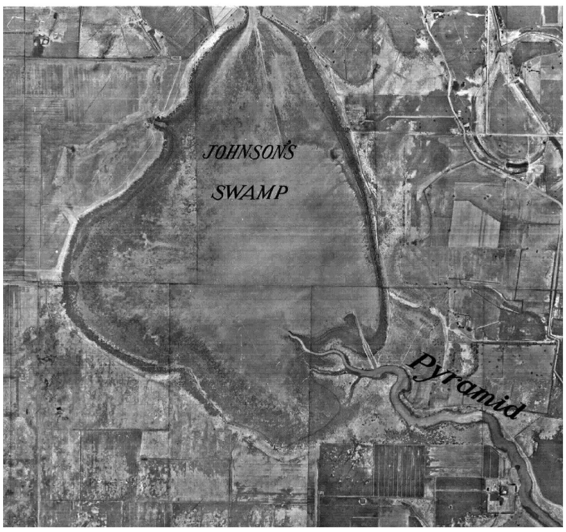
KEY

Dark blue: *Typha orientalis*
Bright yellow: *Typha domingensis*
Aqua: *Phragmites australis*
Dull yellow: *Bolboschoenus / Eleocharis*



3b. Johnson Swamp

Aerial photographs from 1945 (left) and 2004 (right) show the extent of changes within Johnson Swamp in sixty years. The construction of a drain has cut the Swamp into two parts, affected the swamp hydrology differently on each side of the drain, and this has had a significant impact on vegetation.



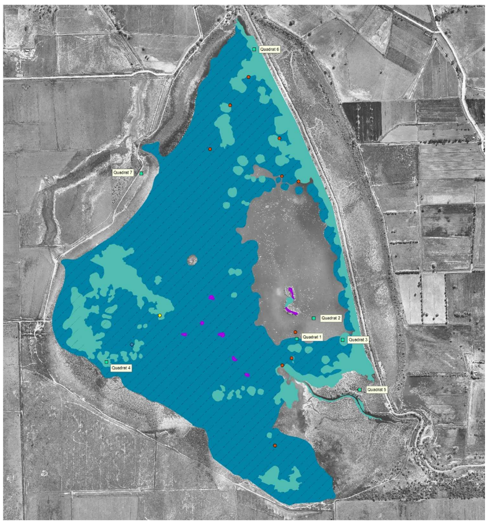
Before hydrological changes, the centre of the wetland would have been covered by Intermittent Swampy Woodland (see above).

Contemporary vegetation: The map shows the distribution of *Phragmites* and native *Typha* at Johnson Swamp. Combined, these cover 57% of the wetland. Note that there is no *Typha* or *Phragmites* east of the drain. These are most abundant in the western part of Johnson Swamp: the eastern part is less frequently inundated.

KEY

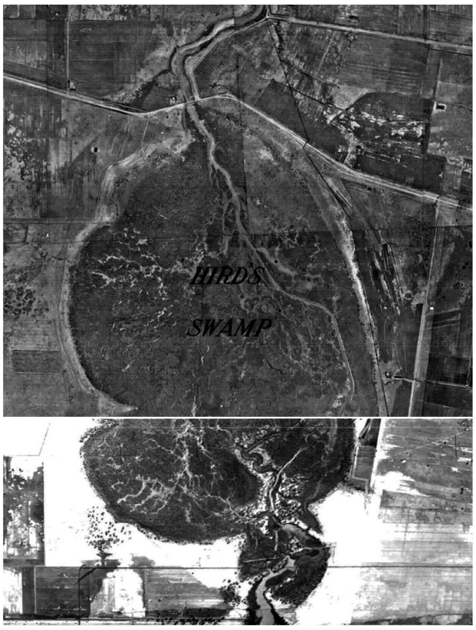
Dark blue: *Typha orientalis*
Bright yellow: *Typha domingensis*

Aqua: *Phragmites australis*



3c. Hird Swamp

Hird Swamp in 1945 (left) compared with 2004 (right), showing the drain that has divided the swamp into two parts.

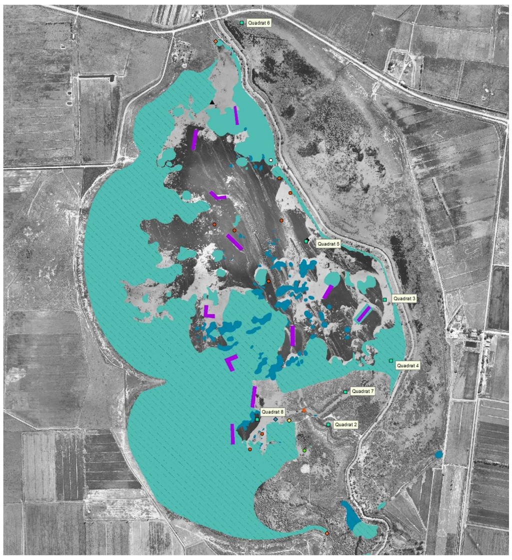


Before hydrological changes, the centre of the wetland would have been covered by Intermittent Swampy Woodland (see above).

Contemporary vegetation: The map shows the distribution of *Phragmites* and *Typha* at Hird Swamp. Combined, these cover 37% of the wetland. Note that these species are most abundant in the western part of Hird Swamp: the part which is east of the drain is less frequently inundated.

KEY

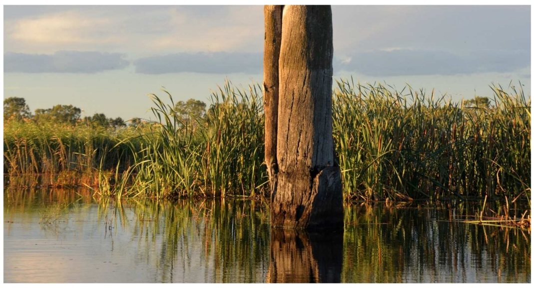
Dark blue: *Typha orientalis*
Bright yellow: *Typha domingensis*
Aqua: *Phragmites australis*



4: Current Vegetation

A pictorial overview emphasising typical spatial organisation, based on Hird Swamp.

Typha orientalis and *Phragmites australis* in the deeper central area of Hird Swamp. Note the dead aboriginal scar tree in the foreground.



Extensive beds of Eel Grass, a submerged macrophyte, help maintain wetland productivity.

Some components of the original understorey vegetation have survived hydrological changes and are still relatively abundant, such as the aquatic herbs Eel Grass, Red Milfoil and Waterwort.

The biomass produced by aquatic herbs such as this is an important component of wetland food webs.

Ribbons (*Triglochin dubia*) was found during a vegetation survey in February 2014.

This species is listed as rare in Victoria. It is likely that this and many other species of wetland herbs were once much more abundant at this wetland prior to changes to hydrology and the subsequent spread of *Typha* and *Phragmites.*

Given the right conditions, including prolonged inundation and high nutrient availability, the cover of *Typha* and *Phragmites* will spread and so decrease the extent of aquatic herbs and herblands. Being fairly tall means that *Typha* and *Phragmites* create dense shade that excludes lower-growing species. *Phragmites australis* produces allelopathic chemicals that further inhibit the growth of other plant species.

5: Habitat balance and habitat quality

While significantly altered from their natural condition McDonalds, Johnson and Hird Swamps support highly significant ecological values including various types of water bird habitat, described below.

Open water areas support large numbers of waterfowl including threatened species such as Freckled Duck (right), which is listed as endangered in Victoria.

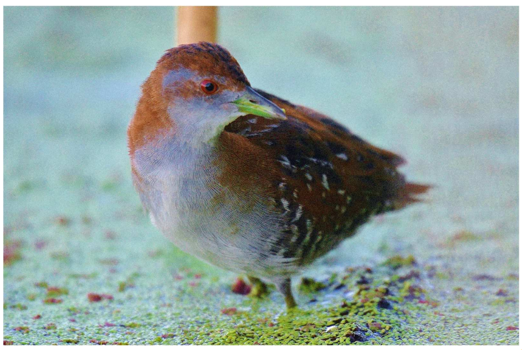
Shallow areas often support a high abundance of frogs and aquatic invertebrates. These food resources are exploited by both large and small wading birds (Right: Brolgas).

Very shallow water and bare **mudflats** are important habitats for migratory and resident small waders such as dotterels, plovers and sandpipers (Right: Sharp-tailed Sandpipers).

Trees surrounding a wetland may be used as calling sites by frogs such as Peron's Tree Frog (right). It comes down to the shallows to mate and lay eggs.

Open to dense wetland shrublands such as Tangled Lignum are utilized by species such as the Spotted Crake and the nationally vulnerable Australian Painted Snipe (Right)

Densely vegetated stands of *Typha* and *Phragmites* provide daytime shelter for cryptic and secretive waterbirds such as the Australasian Bittern and Baillons Crake (Right): however, these birds forage around the edges of dense stands.



Summary: These three wetlands have a range of habitats. When *Typha* and *Phragmites* invade and expand into these habitats they degrade habitat values of that wetland

However, *Typha* and *Phragmites* do provide habitat for a number of threatened cover dependent water birds (including Bitterns and Crakes) and therefore their cover should be controlled but not eliminated.

Large continuous stands of dense reeds and cumbungi are not useful as foraging habitat, whereas stands with gaps, open areas or even bare muds are.

6: Habitat Renewal

Standing dead River Red Gums are an important resource for native fauna. They are used as roosting and nesting sites and contain many hollows.

The White-bellied Sea Eagle is listed as vulnerable in Victoria, with as few as 200 breeding pairs remaining in the state. About 5% of these pairs are in the Kerang Wetlands Ramsar Site, and most of these nest in dead River Red Gums.

River Red Gums at these wetlands were drowned as long ago as the late 1800s, and have therefore been dead for well over 100 years.

Many of these trees are now falling over, which means less roosting and nesting habitat for many birds.

River Red Gum and Black Box have begun to regenerate naturally in parts of all three wetlands.

Environmental watering should be managed to encourage this, and natural regeneration assisted by planting tube stock where no seedling recruitment is occurring.

Replacement and renewal is a long-term process, and will require decades.

7: Watering with care

Environmental water managers must ensure woody vegetation is not drowned, and must be conscious of the combined effects of artificial watering and natural floods.

Scotties Billabong: Scotties Billabong in the Murray Sunset National Park is the example.

In January 2010 (above) it was a fine example of good condition Intermittent Swampy Woodland. But by November 2013, about a quarter of the large, old trees had died, and many others have declined in health.

It is possible that these trees died as a result of prolonged inundation and a corresponding depletion of oxygen in the wetland substrate.

This may have been caused by a combination of the environmental watering in Spring 2009 followed by the natural floods of summer 2010/11.

Nearby wetlands of similar morphology but which had not been watered showed no evidence of widespread recent tree death.

This highlights the need for follow up monitoring in wetlands that receive environmental watering that are subsequently inundated by natural floods.

8: Using water regime to manage *Typha* and *Phragmites*

This section showcases an example of successfully using water regime to manage *Typha* and *Phragmites*.

Black Swamp: Black Swamp occurs adjacent to Nine Mile Creek, south of Numurkah in northern Victoria.

A channel dug from the creek to the wetland increased both duration and frequency of inundation. This drowned the River Red Gums and facilitated the invasion of *Typha orientalis*.

In 2007 the Goulburn Broken Catchment Management Authority built a regulator on the channel, allowing control over wetting and drying of the wetland. Since 2008 the wetland been allowed to dry regularly over summer and this has reduced the vigor of *Typha orientalis*.

An intense wildfire in February 2014 burned many of the dead River Red Gums within the wetland, destroying culturally significant aboriginal scar trees and important wildlife habitat. It also removed dead *Typha orientalis* biomass, leaving very little of this species present.

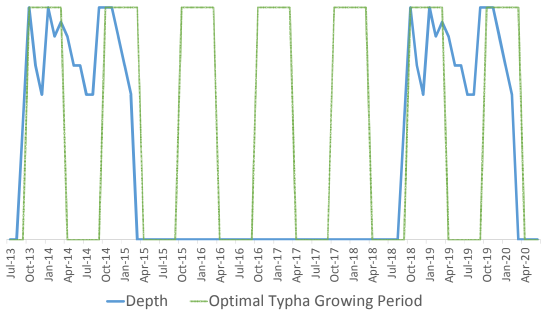
The wildfire was so hot that it appears to have sterilized the soil around where dead trees and logs occurred, as after environmental watering nothing germinated in these areas.

9: Suggestions & Recommendations

Three suggestions and recommendations are made in relation to environmental watering.

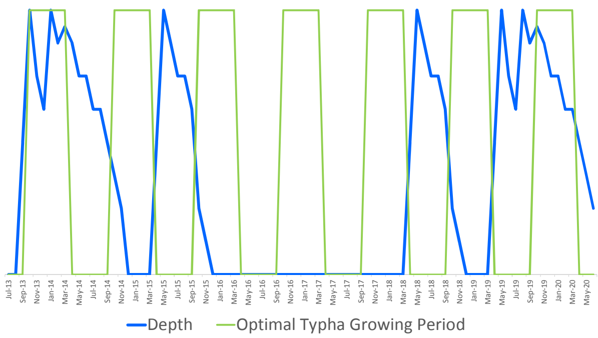
- Minimise watering during the optimal growth period for *Typha* (using Hird Swamp as an example)
- Water adaptively, taking note of natural floods
- Avoid watering on a annually-repeated pattern

Avoid optimal growing period for invasive species: The current environmental water regime results in Hird Swamp being inundated twice in a ten year period, including being flooded for four summers out of ten (see below). Being inundated in summer provides optimal growing conditions for *Typha*.



However, this water regime may allow the continued expansion of *Typha* and *Phragmite*s, causing a reduction in the area and quality of important fauna habitat types such as open water and mudflats.

An alternative watering regime suggested (below) requires a similar amount of water. The wetland is inundated 4 times in a ten year period, but only during two summers. This may maintain or perhaps even reduce the area covered by *Typha* and *Phragmites.*



Experimentation will be required to find a watering regime that will control the spread of these species but not eliminate them.

Be adaptive: Environmental watering should be done adaptively, taking account of natural floods and the growth responses of desirable species such as River Red Gums, Black Box and aquatic herb species, as well as of potentially invasive plants such as *Typha* and *Phragmites*.

Avoid regularity: Environmental watering should *not* follow a strict and regular timeline. As the Australian climate is inherently variable it is important that watering does not occur at the same time, but instead is delivered in various seasons and to various depths and durations. Autumn and winter watering should be more frequent than spring watering to reduce the amount of time the wetlands are inundated during the optimal growth period of *Typha* and *Phragmites*.

10. Key Points for McDonald, Johnson and Hird Swamps

- The invasion of *Typha* and *Phragmites* into habitats where they did not previously occur can degrade wetland habitat values.
- However, *Typha* and *Phragmites* do provide habitat for a number of threatened cover-dependent waterbirds (including Bitterns and Crakes). Their cover should be controlled but not eliminated.
- Appropriate water regimes may be the best way to manage the abundance of *Typha* and *Phragmites* and to restore desirable species such as River Red Gums, Black Box and aquatic herbs.
- The regeneration of a living canopy of trees is critical to maintain habitat quality for birds such as ibis and the White-bellied Sea Eagle which roost or nest in trees.

11. References

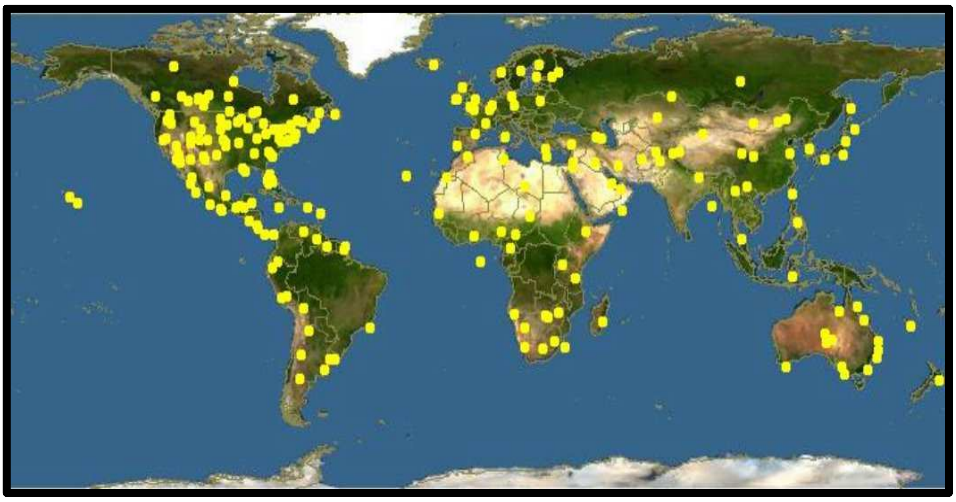
Cook D, Bayes E and Jolley K (2014). *Mapping of Typha species and Phragmites australis in 3 Central Murray wetlands.* Prepared for North Central Catchment Management Authority. Rakali Ecological Consulting, Chewton VIC 3451.

Allelopathy and Phragmites.
Death in the wetland

1: Introduction

Distribution: Common Reed *Phragmites australis* is not the only species of *Phragmites*, but is certainly the most widely known and studied. Currently, world-wide, five species are recognised, however *Phragmites australis* is the most widespread, with a truly cosmopolitan distribution (Chambers et al 1999, Lambertini et al 2008).

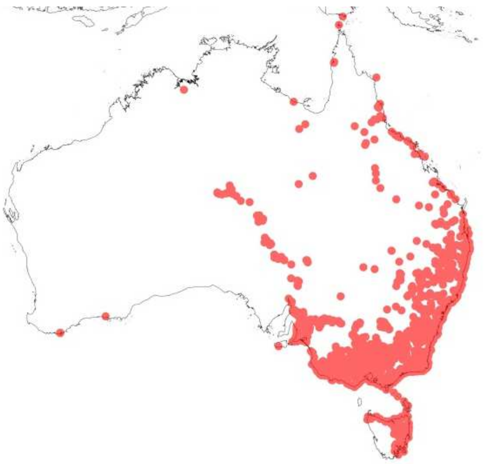
The map below shows the very wide distribution of records of *Phragmites australis* (map from Discover Life: accessed 5 November 2013).



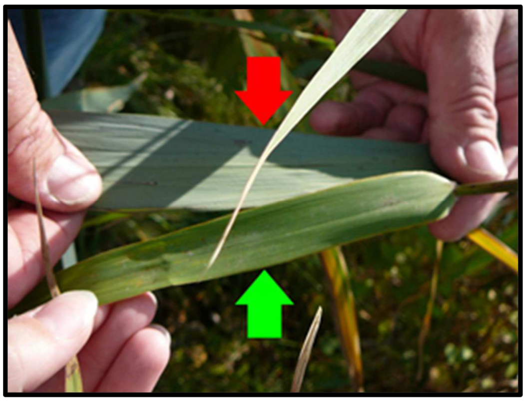
Australia: In Australia, *Phragmites australis* is found mainly in the eastern part of the continent (map of records, right), probably introduced to WA. It even occurs in hot arid inland parts of Australia in waterholes that are permanent.

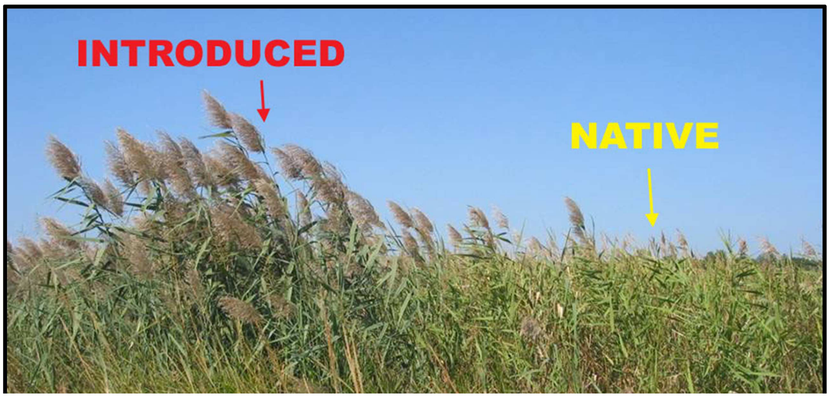
Map downloaded from Atlas of Living Australia, November 2014.

There is another species of *Phragmites* in Australia, *Phragmites vallatoria*, it has a northern disribution. The name *Phragmites karka* is sometimes used for this but *P. vallatoria* is the currently accepted name (Lambertini et al 2008).



Variability (morphological): *Phragmites* is morphologically quite variable, in its vegetative (eg leaf width) and reproductive features (panicle density) (see below). In North America, the native *Phragmites australis* is visually distinct from the introduced genotype, that has established and is invading the eastern seaboard.

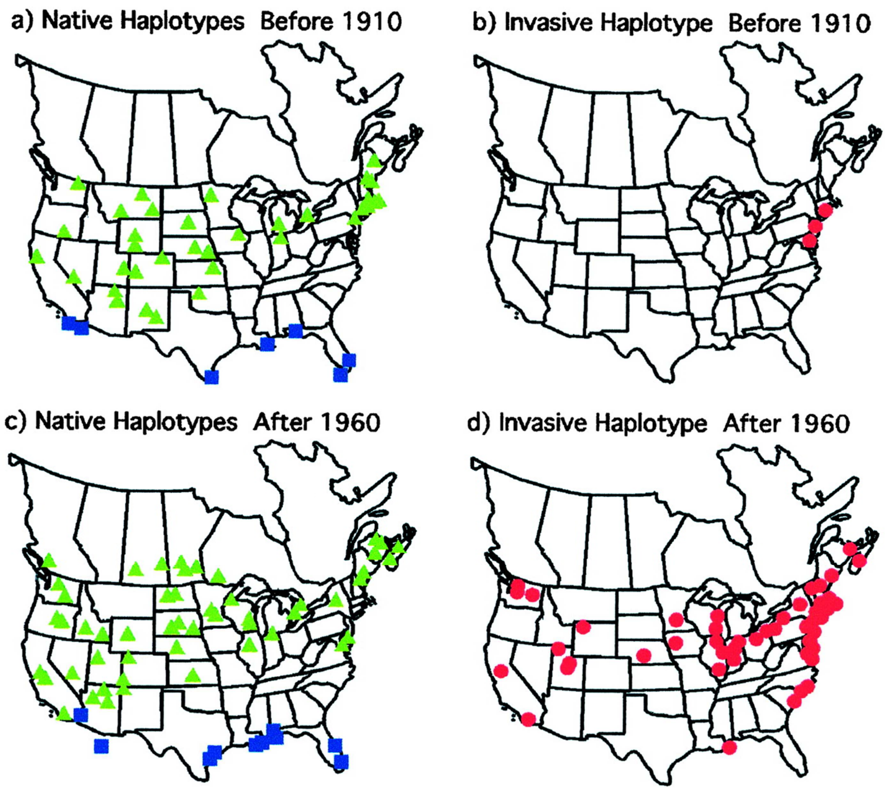




Variability (genetic): *Phragmites* is also genetically quite variable. Ploidy levels may range from 2n to 22n. Diploids (2n) are rare: polyploids (3n, 4n, 6n, 7n, 8n, 10n, 11n, 12n, and 22n) are more common. From limited sampling done, Australia has mostly octoploids (8n) (Clevering and Lissner 1999).

A *haplotype*, meaning haploid genotype, is a group of genes that a progeny inherits from one parent. So far, 27 haplotypes have been identified (Kristin 2002), eleven in North America (where this study was done). The number of haplotypes in Australia is not known.

Haplotypes differ ecologically. In North America, there is a marked difference in the distribution of native and invasive haplotypes through time, as shown by their distribution patterns for two periods, Before 1910, and after 1910 (below, from Kristin 2002). The invasive haplotype has expanded enormously since 1910 whereas the two native haplotytpes (in green, and blue) have barely changed.



2: Observations

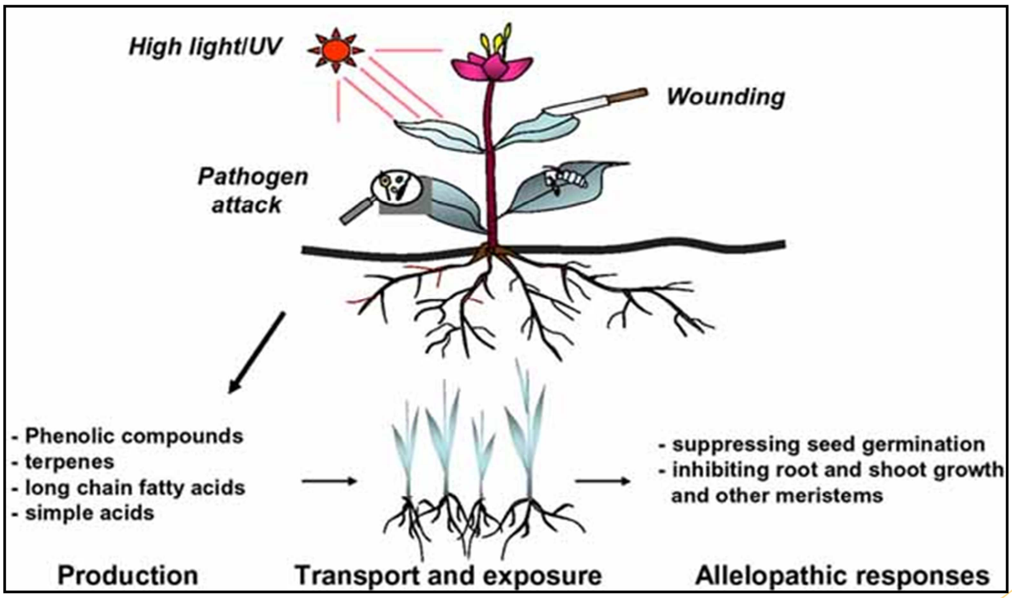
Three species of clonal wetland plants in the Gippsland Lakes area of Victoria (*Typha*, *Phragmites*, *Melaleuca ericifolia*) have a similar 'doughnut' growth pattern, of growing outward and leaving a hollow centre. This 'doughnut' or 'fairy ring' appearance is very evident in aerial photographs (next page).

One possible explanation for this hollow centre is allelopathy.

3: Introducing Allelopathy

Allelopathy can be defined as chemical inhibition. For plants this typically means that chemicals produced and somehow released from one plant can inhibit the germination or growth of another plant.

Release may be triggered by stresses such as wounding, pathogen attack, or high irradiance or high ultraviolet (UV). And, as indicated in the diagram, different types of chemicals are implicated in allelopathy: phenolic compounds, terpenes, long chain fatty acids and also simple acids.



Pathways for allelochemicals: Allelochemicals are the chemicals that cause allelopathy. They are released into the environment via the aboveground parts (leaves, stems) or belowground parts (roots, rhizomes). It is their presence in the environment that affects other plants.

At least two allelochemicals have been identified in *Phragmites australis* (Li et al 2005, Bains et al 2009)*,* that are known to have toxic effects.

- o Ethyl2-methylacetoacetate is an algicide, however its action is species selective. For example, although it does kill *Chlorella pyrenoidosa* and *Microcystis aeruginosa*, it does not kill *Chlorella vulgaris*.
- o Gallicotannins are converted by microbes into Gallic acid (3,4,5-trihyroxbenzoic acid) which destroys tubulin protein in plant cells, leading to lack of structural integrity.

This Study: This study explores one particular type of chemical compound, *phenolics*, for their allelopathic potential. The subject plant is Common Reed *Phragmites australis*. The study had several lines of investigation:

a. whereabouts in *Phragmites* phenolics are located and most concentrated
b. how phenolics extracted from *Phragmites* affect germination and early seedling growth of other plants, using two wetland plants
c. whether concentration is important, using *Lactuca sativa* and *Poa labillardieri* as test species
d. whether phenolics in the plant, in the soil or surface water have similar effects on *Lactuca sativa* and *Poa labillardieri*
e. how fast phenolics extracted from *Phragmites* degrade, under aerobic and anaerobic conditions; and whether the decay rate changes if other sources of energy are available to bacteria
f. whether phenolics are still present in aged litter and still have a negative effect on other wetland plants
g. whether phenolics are still present in dead *Phragmites* shoots
h. whether burning reduces the amount of phenolics in *Phragmites*

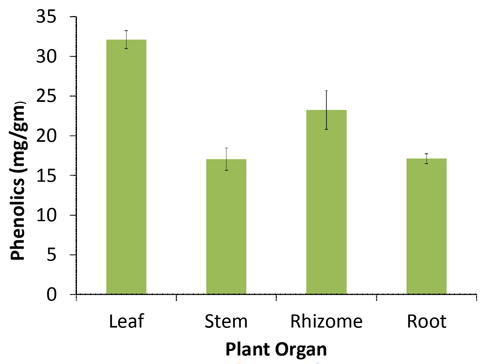
4: Results from experiments and investigations into phenolics and *Phragmites*

4a: Where are phenolics in *Phragmites* ?

Concentration of phenolics in different parts of *Phragmites* plants is shown (right).

Principal findings are:

- o Phenolics are in all parts of *Phragmites*
- o Concentrations of phenolics were highest in the leaf, and lowest in the stem and roots.

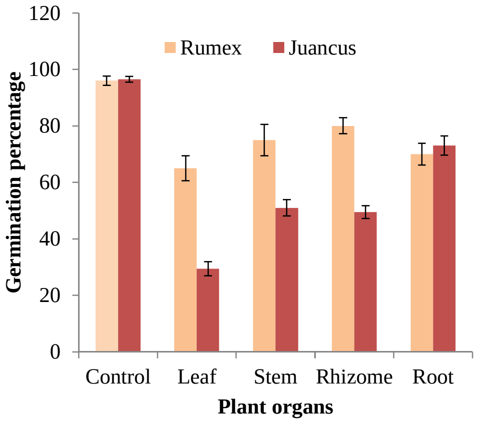


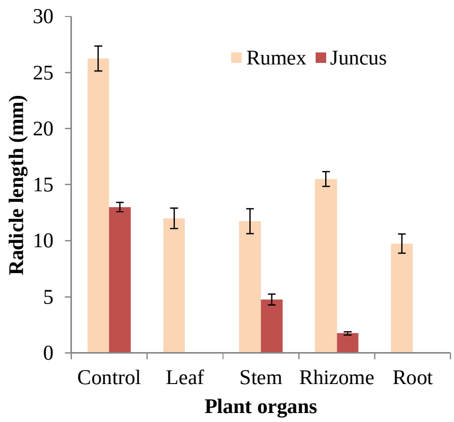
4b: Do phenolics in *Phragmites* affect other plants ?

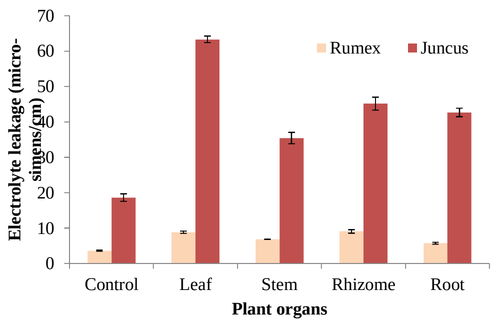
The allelopathic effect of phenolics extracted from different parts of *Phragmites australis* was tested on two common wetland plants, *Rumex* sp (orange) and *Juncus* sp (dark red), in two experiments (next page).

Experiment 1. Germination: The allelopathic effect of phenolics on germination success, and early seedling growth is shown below. Principal findings are:

- Extracts from all plant parts reduced germination % and radicle (rootlet) growth, and increased ionic leakage, relative to controls.
- Leaf parts tended to have more of an effect than other plant parts.
- Both test plants were affected but not to the same amount and not in the same way: *Juncus* was more sensitive than *Rumex*.

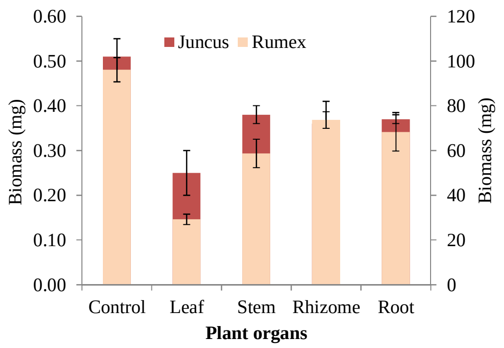


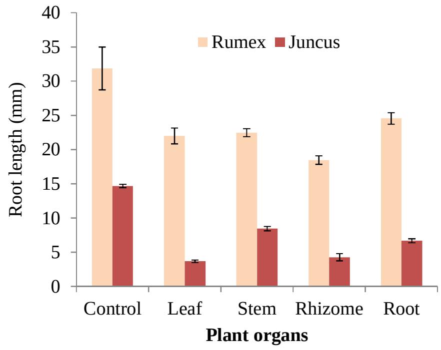


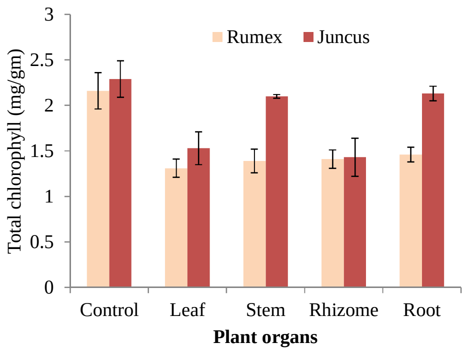


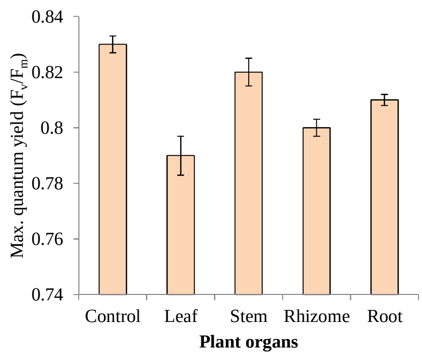
Experiment 2. Early Seedling Growth. The allelopathic effect of phenolics on growth and physiological condition of seedlings is shown below. Principal findings are:

- Extracts from all parts of *Phragmites* (leaf, stem, rhizome, and root) affect seedling growth, as indicated by lower biomass, shorter root length and lower chlorophyll concentrations, than in experimental controls. -
- Effects of extracts from *Phragmites* were similar for both species, except – oddly – *Juncus* biomass.









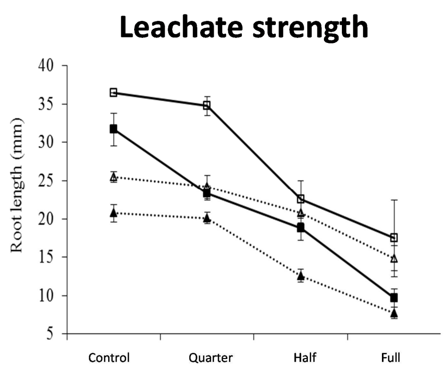
4c: Is concentration important?

This experiment tested whether the inhibitory effect of phenolics is directly related to the concentration of phenolics. For this, *Phragmites* extract was used full strength as well as diluted to one half and one quarter strength. The test species were lettuce *Lactuca sativa* and tussock grass *Poa labillardieri*, and germination and early seedling growth assessed.

Principal findings:

- o Germination of the two test species decreased with increasing concentration
- o There was no indication of any critical threshold concentration
- o The effect was the same for germination as for early seedling growth (root length, biomass).

Only one response is shown (right): root length of early seedlings.

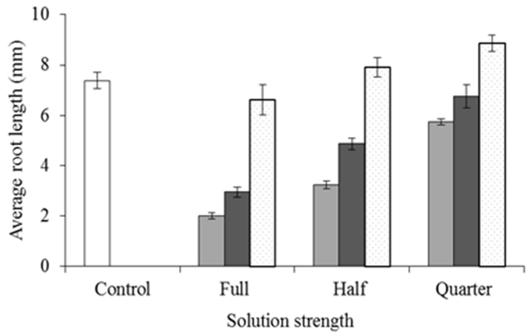


4d: Phenolics around *Phragmites*

Experiments exposing test species to plant extracts are informative but may not represent what is actually happening. This experiment used *Phragmites* extract (as in preceding experiments) and compared this with extract from the soil where *Phragmites* was growing, and the overlying water.

The results on early seedling growth measured as average root length are shown (right). Principal findings are:

- o Leachate extracted from *Phragmites* had a much stronger effect than the soil, or the water.



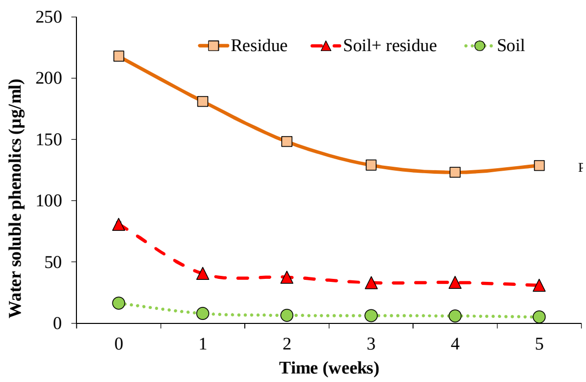
In this plot, white bar = soil surface water, black bar = soil, and grey bar = whole *Phragmites* plant.

4e: Decay rate of phenolics

How long do phenolics stay in the environment?   Do they naturally degrade ?

This was investigated in four short-term experiments that focused on water soluble phenolics. The decay rate was determined by repeated sampling, at weekly intervals over 5 weeks, under the following conditions: aerobic versus anaerobic, with or without additional energy source for microbes (dissolved carbon).

The concentrations of water soluble phenolics in *Phragmites residue*, in *soil + residue* and in *soil*, under aerobic conditions are shown (right).



Principal findings when under ***aerobic*** conditions are:

- o Phenolics showed a significant decline in concentration with time
- o All sources behaved in same way, with an initially rapid decline, and then gradually slowing.

Principal finding under ***anaerobic*** conditions are:

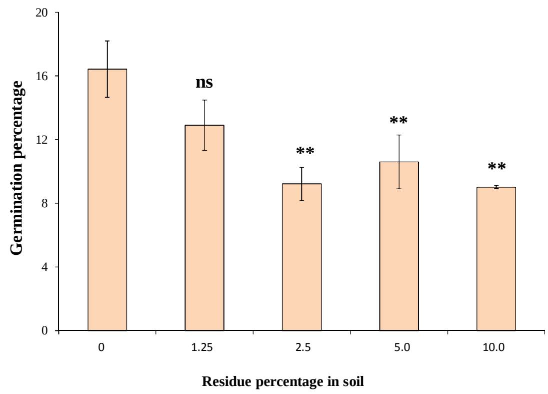
- o Phenolics did not decline (not shown)

In other words, the short-term decay of water soluble phenolics is faster under aerobic conditions.

4f: What about *Phragmites* litter ?

Given that phenolics decay through time, does this mean that old *Phragmites* litter has little – or even no ? – Inhibitory effect on other plants? This idea was tested using seeds of the wetland shrub *Melaleuca ericifolia*, which co-occurs with *Phragmites* in wetlands in Gippsland, and using wetland soils with varying amounts of *Phragmites* residue. As in other experiments, the inhibitory effects – if any – were assessed by recording germination percentage and early seedling growth (root biomass, total chlorophyll).

The germination % for *Melaleuca ericifolia* is low, about 16%, in control soils with no *Phragmites* residue. Results for four concentrations of *Phragmites* litter and Control are shown (right).



Principal findings are:

- Germination of *Melaleuca ericifolia* was inhibited in presence of old *Phragmites* litter.
- Old *Phragmites* litter in the soil had an inhibitory effect on germination, except at lowest residue concentrations tested (1.25%).

Early seedling growth of *Melaleuca ericifolia* was not as sensitive as germination (not shown).

- Root biomass was reduced, but not at residue concentrations of 1.25% and 2.5%
- Total chlorophyll concentrations were reduced, but only at high residue concentrations of 10%.

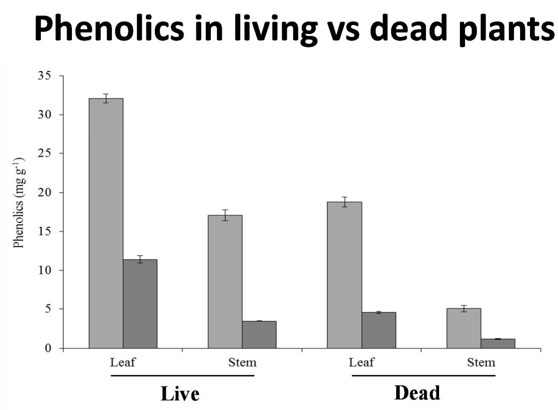
4g: Does *Phragmites* litter have an allelopathic effect ?

As well as persisting in the soil, phenolics could also persist in standing dead shoots of *Phragmites*. This was investigated by comparing the concentration of phenolics in different parts of the plant, and in different condition (lives, dead).

The plot (right) shows total phenolics (lighter grey) and water soluble phenolics (darker grey) in live and dead plant tissues from In the diagram, lighter grey is total phenolics, and darker grey is water soluble phenolics only. Although many bioassay experiments use total phenolics (which are extracted by organic solvents), this study focused on water soluble phenolics, as being more ecologically relevant to natural wetlands.

Principal findings are:

- Standing dead material is still a source of phenolics that can be leached into the environment, however concentrations are much lower than in live shoots



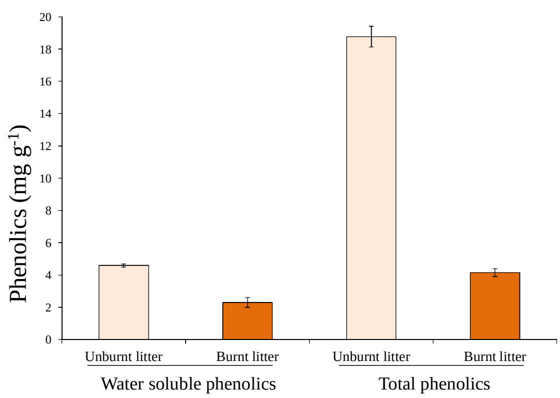
4h: Reducing the amount of phenolics

What can be done in situations where allelopathy is an ecological problem and is preventing the achievement of an ecological goal? This experiment looked to see if burning reduces the quantity of phenolics present.

The concentration of phenolics in burnt (red-brown) and unburnt (pale) litter is shown (right). The experiment was for water soluble and total phenolics.

Principal findings are:

- Burning reduces the load of phenolics present
- Burning has a much greater effect on Total phenolics than on water soluble phenolics.



5. Synthesis

What are we dealing with ?

Phragmites australis exudes allelochemicals into the wetlands and affects other associated plants and influence the structure and biodiversity of wetlands in Australia and allow it to invade into new areas.

'Novel Weapon Hypothesis'

The *novel weapons hypothesis* proposes that some invaders succeed because they possess biochemical weapons that function as unusually powerful allelopathic, defense, or antimicrobial agents. These are 'novel' to the ecosystem where invasion is happening, as the native plants have not evolved coping mechanisms. The allelochemicals of these invaders may be relatively ineffective in their places of origin where their neighbours are well-adapted.

Build up of phytotoxic chemicals

Decomposition of plant residues seems to play a significant role in the build-up of phytotoxic chemicals, and water regime is implicated here. Phenolics decay faster under aerobic conditions (resulting from periodic drying out of subtrate) than under anaerobic conditions (waterlogged soils).

Dispersing and Depleting allelochemicals

Encouraging decomposition is probably the most effective means of reducing the load of allelochemicals, including the introduction of carbon.

6. References

Bains G, Sampath Kumar A, Rudrappa T, Alff E, Hanson TE and Bais HP (2009). Native plant and microbial contributions to a negative plant-plant interaction. *Plant Physiology* 151:2145-2151.

Chambers RM, Meyerson LA and Saltonstall K (1999). Expansion of *Phragmites australis* into tidal wetlands of North America. *Aquatic Botany* 64:261-273.

Clevering OA and Lissner J (1999). Taxonomy, chromosome numbers, clonal diversity and population dynamics of *Phragmites australis. Aquatic Botany* 64: 185-208.

Kristin S (2002). Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *PNAS* 99:2445-2449.

Lambertini C, Gustaffson MHG, Frydenberg J, Lissner J, Speranza M and Brix H (2006). A phylogeographic study of the cosmopolitan genus *Phragmites* (Poaceae) based on ALFPs. *Plant Systematics and Evolution* 258: 161-182.

Li F-M and Hu H-Y (2005). Isolation and characterization of a novel anti-algal allelochemical from *Phragmites communis*. *Applied Environmental Microbiology* 71:6545–6553.

Case Histories

In the opening session, workshop participants identified questions and issues to do with *Typha* and *Phragmites* for discussion.

Questions and issues

- Should I introduce *Typha*?
- What are the management options for plants in drainage systems?
- What general rules for management could feed into guidelines for improving degraded wetland vegetation?
- How does the science inform management decisions and management plans?
- How much is too much *Phragmites* and *Typha*?
- What are the available management tools?
- What are best practices to manage and monitor *Phragmites* and *Typha*?
- What objectives or values should management and monitoring support?
    - For example in response to community needs or expectations for the delivery and drainage of environmental water.
    - A related question for water management is who is using what and to what effect?
- How much shading is required to manage *Phragmites* and *Typha* in urban waterways?
- Is direct intervention in a wetland system sustainable or not?
- Is *Phragmites* ability to store carbon relevant to management decisions?

The number and diversity of questions showed the level of interest in the workshop but a pragmatic decision had to be made, as there were too many questions and issues to work through in the time available.

Four Case Histories were selected. These were chosen because they span a range of situations, so cover 'management' from different aspects and would be expected to inform a large proportion of the workshop.

A fifth Case History, provided after the workshop, is included as an example of successfully controlling vigorous Cumbungi. This links to the presentation by Jane Roberts (pp 11-12) and Damien Cook (pp 34-35).

CASE HISTORY 1: An old water reservoir used for public recreation

Question: Should *Typha* be introduced?

Context

The site is a dam (1000 ML) that once was used as a reservoir but now is used for recreation. The dam is deep, up to 12 m. It is mostly fairly steep-sided except for one part of the shoreline which has a gentle slope, extending out into the water about 20 m before becoming deeper than 1.5 m. There is no capacity to manage the water levels in the dam.

The dam is valued for its birds, particularly its waterbirds. A total of 150 bird species have been recorded, and waterbird numbers up to 750 have been recorded.

Currently there is no *Typha* present and just some *Phragmites*. Habitat diversity for birds would be increased if *Typha*, a tall emergent macrophyte, was introduced and established.

Comments from Participants

Workshop participants were generally rather reserved and cautious about the idea of deliberately introducing *Typha* into the old reservoir.

Their advice and comments consistently and strongly emphasised the need to think through the likely risks of introducing *Typha*.

- If you are thinking of introducing a new species, then ask "*Why isn't it there already*?"
- Once *Typha* is established, it will be difficult and costly to eradicate at a later date
- *Typha* is invasive and competitive, and there is a risk it will take over shorter vegetation types
- Consider the available habitat for *Typha:* use its min-max depth range as a guide to how much and what parts of the wetland it could occupy
- What type of habitat are you trying to achieve? Can this be provided by another tall emergent macrophyte that does not have invasive characteristics?

Workshop participants also emphasized the importance of re-visiting the management goals, or finding a different answer.

- Understand what you are doing already and ask "*Will the proposed change make a significant difference*"?
- If the goal is to increase bird diversity by increasing habitat diversity or introducing a type of habitat not already there, then consider using a less invasive species to get structural diversity (height).

The consensus was to apply the precautionary principle

- Avoid using *Typha*

Information and Resources

Several information sources were identified that can be useful when making decisions like this one.

Melbourne Water have produced constructed wetland guidelines
www.melbournewater.com.au/planning-and-building/standards-and-specifications/design-general/pages/constructed-wetlands-guidelines.aspx

DEPI have produced information about wetland ecological vegetation
www.depi.vic.gov.au/water/rivers-estuaries-and-wetlands/wetlands

Office of Living Victoria have produced a publication on whole of water cycle management (see www.livingvictoria.vic.gov.au/what-is-whole-of-water-cycle-management)

West Gippsland CMA have produced Waterhole Creek Waterway Management Plan (www.wgcma.vic.gov.au/index.php/component/content/article/72/362-waterhole-creek.html

Knowledge Gaps & Researchable Issues

- Shading an area with *Typha* will lead to a change in water temperature (it is suggested that the temperature difference could be as high as 10 degrees Celsius cooler), and this may affect chytrid levels and subsequently amphibian populations.
- State of the wetland seed bank

CASE HISTORY 2: Urban drains & irrigation channels

Question: What to do about *Typha* and *Phragmites* ?

Context

Stands of *Typha* and *Phragmites* can establish on channel banks or in waterways that are used to remove water (drains) or to deliver it (irrigation channels). These stands can become a management headache, affecting neighbours as well as users, with no obvious means of control.

Urban case history: In an urban situation, blocked drains can cause localized flooding. A drain blocked by *Phragmites* forces stormwater to back up and spill round; and at the same time silt is deposited. The silt is colonized by *Phragmites*, and the situation compounds. The *Phragmites* can be dug out but, from experience, this is very labour intensive and not very successful in the long-term, as *Phragmites* grows back again. Particular questions posed for this Case History were:

- If the *Phragmites* can be removed, would it be wise to plant in something else to prevent *Phragmites* re-establishing; and if so, then what should be planted ?
- Is shading a viable management tool ?

> An off-label permit is where an organisation or individual or body makes an application to the Australian Pesticides and Veterinary Medicines Authority (APVMA) to use a product outside the conditions specified on the label of that product. This is sometimes done for certain aquatic weeds that are not listed or covered for control adequately. The permit will give a timeframe for use, specific conditions of use, jurisdiction for use, and additional conditions which generally include several "Do Not" statements to minimise herbicide entry into the waterways with the aim of protecting the aquatic environment.

Irrigation channel case history: Irrigation channels with leaks or seeps create a habitat for *Phragmites* or *Typha* outside of the channel. Once it is established, these plants (but especially *Phragmites*) can expand into adjacent private land where they are not wanted. Neighbours can require the water company to control *Phragmites* or *Typha.* If the patch is small, then control (when measured by effort and dollars per unit area) becomes a relatively expensive exercise. Control in this situation is recurrent, so maintenance of the weed becomes an on-going issue for the water company, and for the affected landholders.

For the water company, whatever management option is chosen (control, remediation), the costs are significant, whether it is remediation which requires locating the leak and fixing the channel, or control which requires treating the plant chemically and annually. Effective chemical treatment uses an off-label chemical mix (explained in box on right). As many irrigation channels are old and ageing, the situation is likely to be repeated elsewhere.

In both these case histories, the individuals managing *Phragmites* felt there was an additional challenge of managing community expectations, about what could be done, and with what degree of success. This was an unexpected aspect of their work, one that goes beyond site and works at the site, and begins to include institutional roles and responsibility.

Comments from Participants

Workshop participants recognised that these two case histories were, in fact, legacies: legacies of past decisions, of past planning and design, and past construction and development. Being a legacy means that the problem is likely recur or even re-appear somewhere else. For this reason, whatever insights can be gained about design, or construction issues at the site, really must be treated as useful knowledge, and passed on to be incorporated into future planning and works design.

As a general principle, workshop participants considered it better to tackle the cause of the problem, rather than the symptoms. They also considered that managing plants such as *Phragmites* (or trying to) was really misdirected effort. Admittedly, however, tackling the cause is rarely easy.

For the urban drain Case History, tackling the cause of the problem could mean preventing the sediment from reaching the site by investing in upstream silt traps; even better, it could mean identifying where the sediment is coming from, and addressing the problem at its source, perhaps by preventing whatever activity is causing this. For the irrigation channel Case History, this means investing in repairing the channel bank; or thinking system-wide about the ageing infrastructure and what's needed.

However, if the decision is made to continue to treat the symptoms, then the options are limited to spraying, excavation, knowing that these have limitations.

It is often forgotten or overlooked that urban drains mostly connect with natural creeks or wetlands downstream; and that untreated stormwater, or even some of the control actions, can have a downstream impact. A holistic view is needed; and at the planning stage, also. Treating stormwater as a site-specific issue only, is avoiding responsibility for aquatic ecology further downstream.

Information and Resources

Information sources that could be used to guide decision making and education initiatives include:

Melbourne Water has Dobson Creek as an example
www.clearwater.asn.au/user-data/case-studies/plans-designs/Case-Study_Wicks-Reseve_FINAL-WEB-3p.pdf

University of Melbourne is researching urban streams; see the Little Stringybark Creek study
www.urbanstreams.unimelb.edu.au/;
www.melbournewater.com.au/aboutus/news/Pages/New-planning-overlay-protects-Little-Stringybark-Creek-.aspx
http://www.stormconsulting.com.au/projects/grassroots-protection-of-little-stringybark-creek/)

Knowledge Gaps & Researchable Issues

The gaps identified in discussion were to do with site-specific control measures (below) but from the discussion clearly there was a need for a 'bigger picture' to be incorporated.

- Understanding (perhaps quantifying) the benefits of different methods of control, such as mowing or spraying. Knowing what method to use and how to use it most effectively. Knowing whether timing of control effort (relative to the annual cycle of plant growth) is important; and how to get smarter.

- An evaluation of shading as a control measure, or biomass reduction measure. How effective is it ? And if potentially effective, then also some practical advice on how best to apply shading.

CASE HISTORY 3: Natural wetlands with managed water regimes

Question: What to do about undesirable outcomes?

Context

Environmental water has been delivered to regionally important wetlands over the last few years, often to meet ecological objectives to do with waterbirds. However, the water requirement for breeding waterbirds also provides optimal conditions for tall emergent macrophytes such as *Typha* and *Phragmites*, and, as result, these two plants have been increasing; and this is evident in the wetland as either as more patches or bigger patches or both.

This increase in Tall Marsh EVC at the expense of other wetland EVCs is a concern to the relevant wetland managers, such as North Central and Corangamite CMA, as it means the habitat value of the wetland is changing. The fear is that if *Typha* or *Phragmites* continue to expand and become dominant then other wetland plant communities with different structural characteristics, will be reduced (or even lost ?), and the value of the wetland as a habitat for a particular group of waterbirds will decline.

Comments from Participants

Management objectives were seen as the issue here. Workshop participants felt strongly that the solution lies with re-visiting how management objectives are expressed or are being implemented; and that some fine-tuning is definitely necessary.

Particular points raised were:

- Management objectives should not be treated as set in stone. They need to be a bit flexible. They need to be able to respond to monitoring and feedback at the site. They need to be able to respond to changes in the regional landscape.
- Risks need to be factored in. Recognise and be explicit about possible ecological risks of delivering a particular objective. Providing a long duration watering to allow waterbirds to complete breeding is detrimental to some plants but favourable to *Typha* and *Phragmites*.
- Re-phrase a potentially risky objective so as to minimise the risk: either by watering less frequently, or by providing waterbird breeding opportunities elsewhere within the region.
- Take note of management history; note what the trends are, think of cumulative effects; try to project where its going.
- Water regime is almost the easiest thing to modify: so look at this first.

Managers were urged to be resolute. It is better to treat the cause, rather than the symptoms, but recognise that the community sees the symptoms and that's where pressure can come from.

More than anything, workshop attendees emphasised the importance of being holistic, taking a landscape view, and seeing the wetland as part of a much bigger regional biodiversity. Particular points raised were:

- It is not necessary for a wetland to provide a waterbird breeding opportunity *every* year. Wetlands can be watered in rotation; and waterbirds can move. Take a *landscape* perspective.
- Be careful not to cherry-pick the science to suit preconceptions.
- It's not just about waterbirds…. there are turtles, frogs ….

Workshop participants pointed out that, of all the many things affecting a wetland and affecting plant growth, that for regulated wetlands (where there are controls on inflows and outflows), water regime is the easiest for a wetland manager to modify.

- Best defence against *Typha* and *Phragmites* is to implement a long drying regime, over summer
- Any modifications to watering regime absolutely MUST be accompanied by some documentation, some evaluation, some feedback and MUST have a statement of what's expected to happen.
- If considering a drying regime, then wise to do a risk assessment for acid sulphate soils first.

Information and Resources

Information sources that could be used to guide decision making and education initiatives:

Lower Barwon Wetlands example. See
www.ccma.vic.gov.au/admin/file/content2/c7/Lower%20Barwon%20Wetlands%20-%20Future%20Water%20Management%20Options%20for%20Consultation-1.pdf

Acid sulfate soil risk report

http://www.environment.gov.au/system/files/resources/bcef08f2-0c60-4931-9b5e-1522ca55da74/files/guidance-management-acid-sulfate-soils.pdf

Alluvium (2013). *Analysis – mobilising contaminants at Reedy Lake.* Report by Alluvium to the Corangamite Catchment Management Authority.

Reports useful in assisting decisions on monitoring programs

Price C, Gosling A, Golus C, and Weslake M (2007). *Wetland Assessment Techniques Manual for Australian Wetlands.* http://www.wetlandcare.com.au/index.php/info-and-links/monitor-my-wetland/

Baldwin DS et al (2005). *Recommended Methods for Monitoring Floodplains and Wetlands.* MDBC Publication No. 72/04. http://www.mdba.gov.au/sites/default/files/archived/mdbc-tlm-reports/2_Recommended_methods_monitoring_floodplains_wetlands.pdf

CASE HISTORY 4: Natural wetlands with no easy water management options

Question: What is the right type of control effort? What is the right level of effort?

Context

Wetlands with no opportunities for controlling water inflows or outflows present one of the greatest challenges for managing *Typha* and *Phragmites*. The challenge feels even greater if the wetland is a high profile site, such as a Ramsar wetland, or is the only remaining representative of a type of wetland in a bioregion, and is already well-covered by *Phragmites* or *Typha*.

In this instance, management found it valuable to establish a firm knowledge of the wetland, through commissioned projects. This revealed certain changes since European settlement (sedimentation) and how such changes were now constraints to managers, as well as exacerbating the problem of the invasive emergent macrophytes.

Selective use of fire and herbicides now seem to be the most likely means of control. But as this is a novel situation, it will require an adaptive management and monitoring.

There is some uncertainty and uncomfortableness with this approach due to using herbicides, even though it does seem to be the only practicable approach. And hence raises the awkward questions about how much effort should be put in to this?

Comments from Participants

The scale of the questions being posed was challenging for workshop participants, and many of the comments focused on clarification of underlying issues.

Particular points raised were:

- The importance of evaluating management goals and risks, which should include the Do Nothing option
- Understand the ecological trajectory of the area of interest: if it is on a projection to become different then is it sensible to be reversing that? Or perhaps trying to look forwards to the future?
- Is it necessary to treat *all* the areas of *Typha* and *Phragmites*? Are there target areas and special reasons? Is it possible to accept some areas as *Typha* and *Phragmites*?
- Is the Ramsar ECD (Ecological Character Description) a target – or even a constraint?

Knowledge Gaps & Researchable Issues

- Long-term change and ecological trajectory
- The effectiveness of the selective use of burning and herbicides in the short and longer term?

CASE HISTORY 5: Successful reduction in vigour

This Case History is included as it provides an example of successful control of Cumbungi (*Typha* spp.). The site conditions are quite special, and this makes control by water regime (deep flooding) feasible.

Sandilong Creek is 1.5km long with two levee banks at either end. This provided the potential to lower and raise the water levels.

Cumbungi was problematic for the Riverside Golf Club as it choked the Sandilong Creek system. The creek was permanently inundated, with its water level maintained close to the Mildura weir pool level of 34.4 AHD. This provided an opportune environment for cumbungi to thrive and dominate the system. The dominance of cumbungi created an issue because it could be dislodged and block areas of the creek line, it limited the creeks capacity to support a more diverse ecosystem, and created other management issue for the golf club. The Riverside Golf Club had been attempting to manage cumbungi in the Sandilong Creek through expensive and ineffective means. The various control measures include: use of an excavator to dig out the vegetation from the creek line, weed spray and regular slashing; all with limited success.

In 2011 Mallee CMA introduced a new program to manage the waterway: altering the water level. Mallee CMA believes that the permanently inundated wetland provided an ideal environment for cumbungi growth and that the growth pattern of cumbungi needed to be disrupted. Cumbungi was flooded over the summer months, fully submerging the leaves over its growth period (water levels +1m), hence stopping it from photosynthesizing and storing energy. During the winter months the water levels were dropped, and any rhizomes above the ground were thus exposed to frosts that killed off buds that could potentially create new leaves in the future. Environmental water (150 ML) has been provided three times since 2011. The watering events occurred over the months September 2011 to June 2012; December 2012 to May 2013; and December 2013 to May 2014. Cumbungi levels were observed to have declined considerably after the first watering event, and the second and third events assisted further with its control, and in improving the ecosystem values.

The Environmental Water Management Plan (EWMP) for Sandilong Creek will be available soon; this can be used as a reference for this watering information.

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