Remapping the distribution of Common Reed along the Wimmera River using satellite imagery. Why has the distribution and abundance changed in the last 15 years?

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Key Points

- Satellite spectral analysis was successfully used to help map the distribution of Common Reed along the Wimmera River.
- Common Reed cover has reduced in the 14 years from 2005 to 2019.
- Analysis of plant and sediment material has shown a consistent reduction in nutrients downstream from Horsham to Jeparit.
- Macronutrients, nitrogen and phosphorus, are seasonally translocated between above-ground and below ground biomass within Common Reed and effectively retained in the river system unless removed from the channel.
- The movement downstream, removal or decay of nitrogen and phosphorus from the river system is much slower than previously assumed.

Abstract

Common Reed (*Phragmites australis*) was mapped and its distribution quantified along the Wimmera River between Horsham and Lake Hindmarsh in 2005 using aerial photography and video imagery. The Wimmera Catchment Management Authority (Wimmera CMA) was interested in understanding if that abundance and distribution had changed in the subsequent 15 years in response to management actions and other natural factors. Spectral analysis of multi wavelength 2019 satellite imagery was used to map and quantify Common Reed abundance, and comparisons were then made with the 2005 data. Nutrient analysis of Common Reed plant material and sediments was also undertaken in 2005 and repeated in 2021. The nutrient analysis provided insights into the mode of spread and contraction of Common Reed patches over the 15 year assessment period. This work successfully used satellite imagery to identify, map and quantify a specific aquatic plant within a river system. This remote sensing approach has application for other plants of interest to quantify distribution and abundance, particularly over large areas or within remote, difficult to access areas.

Keywords

Common Reed, *Phragmites australis*, spectral analysis, plant mapping, nutrient analysis, Wimmera River

Introduction

This project was designed to quantify the distribution and abundance of aquatic vegetation (primarily Common Reed, *Phragmites australis*, hereafter referred to as Phragmites) in the lower Wimmera River from Horsham to Lake Hindmarsh, western Victoria, Australia. This project has been divided into two Phases. Phase 1 identified changes in the distribution and abundance of Common Reed between 2005 and 2019. Phase 2 involved a nutrient and biomass assessment to determine if changes in cover and distribution are likely to be flow or nutrient driven, or from some other observed impact such as grazing, fire or increased inundation.

Phase 1 Mapping of Phragmites

The mapping and quantification of Phragmites in 2020 was undertaken using three key steps. These steps were:

1. Field identification of large patches of Phragmites and differentiation of other emergent species including Cumbungi. Large pure patches of Phragmites were identified to help train the spectral analysis.
2. GIS spectral analysis of the satellite imagery to classify areas of Phragmites.
3. GIS digitisation of blockages using the spectral analysis derived Phragmites patches and visual band satellite imagery.

1 - Field identification of Phragmites patches

Large Phragmites patches, clear of overhanging canopy, were identified in the field and later digitised as polygons that were then provided to the spatial analysist to help train the spectral analysis.

Figure 1. Large Phragmites patches identified downstream of the Dimboola Weir (left) and downstream of the Western Highway (right)

2 - Satellite imagery spectral analysis

This project has adopted the use of spectral analysis of satellite imagery to assist in the mapping of Phragmites along the project reach of the Wimmera River. WorldView-2 imagery was selected as the most appropriate due to the cost and timing (within the Phragmites active growing season) of image capture.

The WorldView-2 satellite imagery is ideal for mapping Phragmites because of its 8-band multispectral resolution which can discriminate ground objects (including plant types such as trees and Cumbungi) better than the traditional 3 or 4 band satellite imageries. The mapping entails the complementary use of visual interpretation and digital analysis techniques such as the automated image classification using ESRI ArcGIS Pro desktop software. For the former, the development of an image interpretation key, or a visual guide to image interpretation, is a valuable tool even when the imagery resolution is high enough to distinguish different objects on the ground. It serves two purposes, namely as (a) a means of training inexperienced personnel in the interpretation of imagery, and as (b) a reference guide for experienced interpreters to organise their information. For the latter, the collection of good field and secondary data (i.e. training samples) is important.

A sample image interpretation key of some land cover type as seen in the WorldView-2 image around the Wimmera River is shown in Figure 2. The spectral value of different land cover types across all 8 bands is displayed in Figure 3. Bands are chosen for land cover type classification where they differ most from others.

For example, Phragmites classification will use Bands 6 – 8 where the spectral value is more removed from most other land cover types (green line), whereas Band 3 might be used to classify built-up areas (grey line).

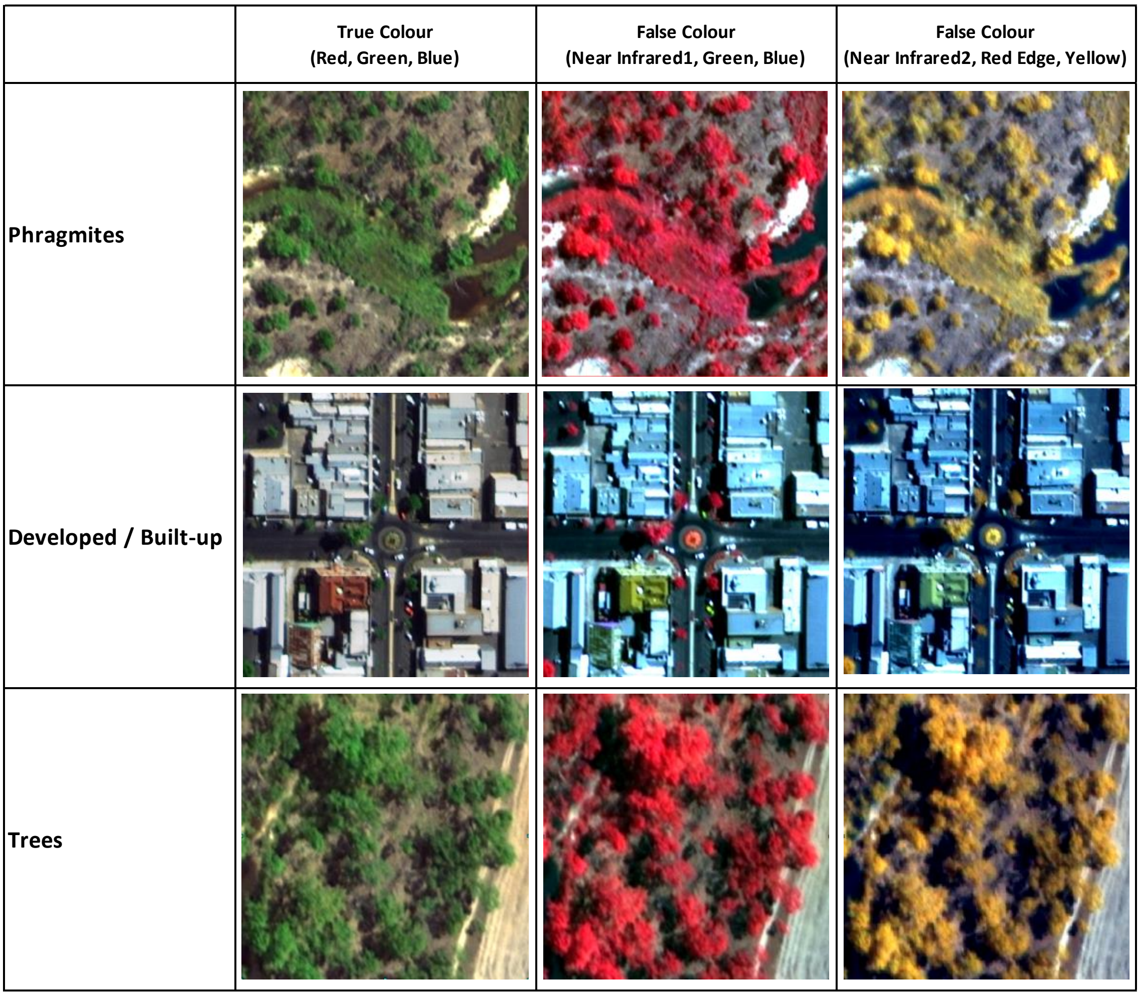

Figure 2. Sample image interpretation of differing land cover types

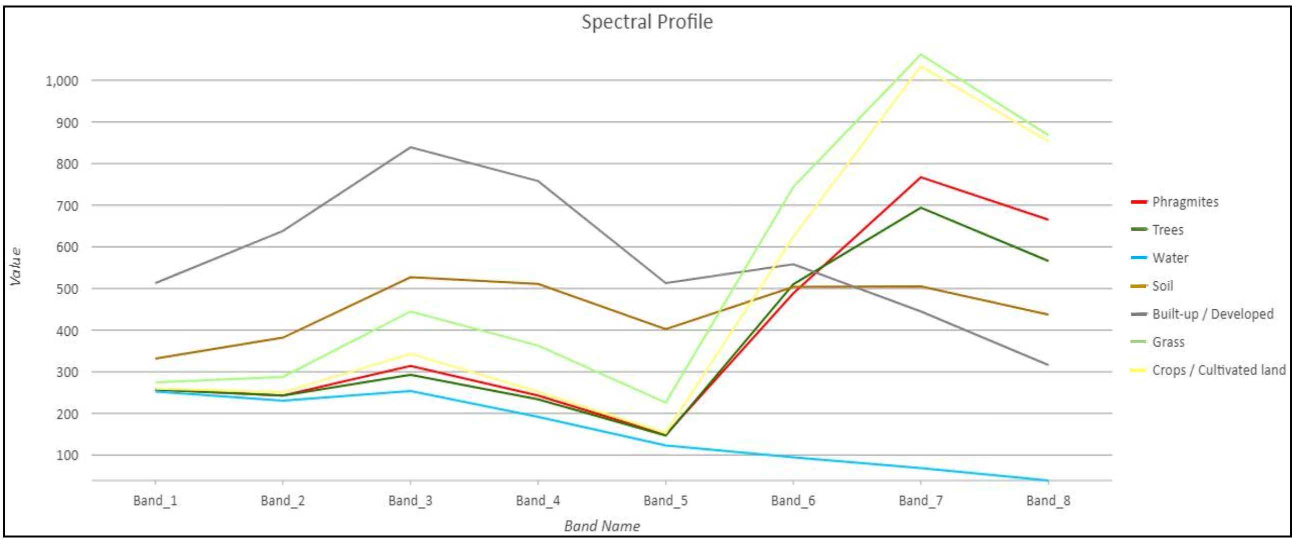

Figure 3. The spectral response of each land cover along the 8 bands

3 - GIS digitisation of Phragmites blockages

The digitisation of Phragmites blockages (i.e. full channel width Phragmites patches) was undertaken by manually plotting polygons around blockages while referencing the 2019 Satellite imagery 'Natural Colour' band and the Phragmites polygons derived from the spectral analysis. The spectral analysis helped to confirm the visual identification of Phragmites in the bed of the river and distinguish it from other macrophytes such as Cumbungi. The length and area of polygons identifying Phragmites blockages was automatically calculated and compared with the 2005 mapping results (from AV June 2006) (Table 1).

Table 1. Summary changes in Phragmites blockages from 2005 to 2019

Date	Total no. blockages	Total length of blockages (m)	% length blockages	Average length of blockages (m)	Total area of blockages (ha)	% area of blockages
2005	200	25,020	17%	125	45.2	12%
2019	236	16,483	11%	70	41.8	11%

Whilst there is still a high density of Phragmites across the project area like in 2005, the results from 2019 show a measurable decline in cover. The following points summarise the comparison of Phragmites blockage results:

- The overall length of blockages has decreased from 17% of the river length to 11% suggesting there has been a clear reduction overall in Phragmites cover.
- The number of blockages had increased from 200 to 236. This is presumed to be due to fragmentation of larger blockages present in 2005. This fragmentation was evident where multiple smaller blockages were digitised in 2019 where a single, larger blockage was present in 2005. Furthermore, the average blockage length has declined substantially from 125m to 70m (44% decline).
- The total area of blockages has declined only slightly from 12% of the channel area to 11%. This is almost certainly due to the differences in blockage digitising techniques and measurement based on the technology and budget available at the time (e.g. satellite cf. aerial imagery).

Phase 2 Nutrient Analysis

This project aimed to replicate the sampling and analysis that was undertaken in 2006 by Agriculture Victoria (AV Nov. 2006). Phase 2 field sampling collected above and below ground Phragmites samples, as well as soil/sediment samples from 12 sites within the project area (Figure 4).

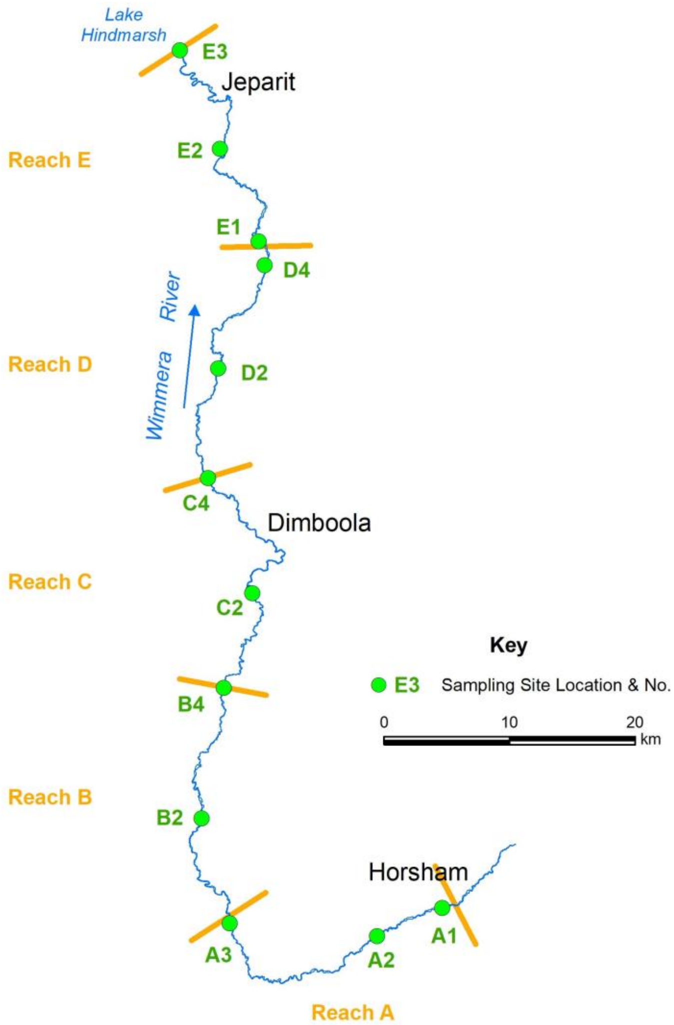

Figure 4. 2021 Project reaches and field sampling site locations

Phragmites above ground sampling

Once a suitable Phragmites patch was located in the field, the assessors walked into the patch and found an area where the plants looked representative/average for the stand (e.g. considering shoot height, density, ratio of dead to live shoots and presence or absence of inflorescence). The assessors ensured the sample quadrat was located at least 2m from the margins of the patch to avoid edge effects.

A dismantlable PVC 0.25m^2 quadrat, with internal dimensions of 0.5m x 0.5m, was manoeuvred into place and joined to identify the quadrat sample. The Phragmites surrounding the PVC quadrat were then laid down to clearly expose the sample quadrat (see Figure 5). The Phragmites were then harvested using secateurs and cut off as close to the ground as possible. Harvested Phragmites were then be collected, placed into a bundle and evaluated outside of the patch (number of live and dead stems, length, basal node width, weight). Samples of live and dead stems were bagged, labelled and placed directly into the car fridge.

Figure 5. Above ground Phragmites sampling

Phragmites below ground sampling

Below ground biomass samples were collected from the centre of above ground sample quadrats by digging a hole 30cm by 40cm, and 30cm deep (Figure 6). A steel mesh 30cm by 40cm was placed on the ground over the harvested quadrat to set the outline for the hole and a tape measure was used to ensure the required depth of 30cm was met. All soil was placed into a large container before being processed. From below ground samples all rhizomes and substantial root masses were separated from soil, usually requiring washing in the river to separate soil from the sample. Rhizomes and roots were carefully washed, blotted dry (when necessary) and weighed. The total biomass from each sample was weighed and a sample was then bagged, labelled and placed in the car fridge for preservation prior to dispatching for laboratory analysis.

Figure 6. Below ground Phragmites sampling

Sediment sampling

Soil samples were collected using a PVC tube corer with an internal diameter of 32mm and sampled to a depth of 10cm. Five cores were collected from within the same Phragmites patch, and from similar positions in the river channel as the biomass sampling quadrat location. The five samples at each site were combined in a zip-lock bag, labelled and also placed in the car fridge.

Laboratory Assessment

Sub-samples from each site (approx. 500 g) of live shoots (Live Above Ground; LAG), dead shoots (Dead Above Ground; DAG), rhizome/root stock (Roots) were transferred to the laboratory at 5°C. Entire soil samples from each site (5× soil cores of 3.2 cm diameter and 10 cm depth; mixed) were also transferred to the lab for further processing. Using a variety of laboratory techniques, the following was determined:

- Vegetation dry weight (LAG, DAG and Roots)
- Dried samples of LAG, DAG, Roots and Soil were sent to the Environmental Analysis Laboratory (EAL) at Southern Cross University (Lismore) for nutrient analysis. Carbon, nitrogen and sulphur were determined by combustion (LECO TruMac) while phosphorus was determined by acid digestion linked with inductively coupled plasma (ICP) spectrometry. All analyses were reported as: mg-element/kg-sample.
- Soil moisture content and bulk density
- Organic carbon content of the soil (using Loss on Ignition)
- Soil texture using the Bouyoucos technique (Beretta et al. 2014)

Laboratory results

The 2021 biomass and nutrient results were compared with the previous assessment and reporting undertaken in 2006. The 2021 findings, and comparisons with 2006 results, are summarised as follows:

- Biomass: Biomass (kg/m^2) was highest in reach C and higher than in 2006 across all sites; root biomass decreased downstream.

- Nutrients: The N and P content of LAG decreased downstream; N-content of DAG increased downstream while the P-content of DAG was approximately constant. Nutrient content of rootstock (both N and P) decreased downstream; LAG was relatively more enriched in N and P than rootstock, while DAG was relatively depleted in N and P. This is consistent with the recovery of plant nutrients during senescence and storage in the rootstock. At all sites the N and P content of live shoots suggests that nitrogen was limiting, with most samples reporting N contents <10 mg/g (compared to N-limited threshold of 20 mg/g). A general trend of increasing N-limitation was observed from upstream to downstream reaches. At the lower reaches there was also evidence for P-limitation. All sites investigated were more N-limited than 2006.

- Sediments: Sediment varied between sandy loam to loamy sand, with a general trend to more sandy soil at lower reaches. The exception to this was the sediment at reach E which are potentially influenced by finer sediments settling out on approach to Lake Hindmarsh. Bulk density was lowest at reaches B and C (both less than 1.4 g/cm^3) and increased significantly at reaches D and E (both greater than 1.6 g/cm^3). Soil and sediment bulk density is known to influence plant growth, with bulk densities > 1.6 g/cm^3 inhibiting plant growth (McKenzie et al. 2004), suggesting that the most conducive condition for plant growth occur at reaches B and C. Moisture content variations across the reaches were essentially the inverse of the bulk density, with maximum moisture content at reaches B and C. Sediment nutrient levels were maximum at reaches B and C, decreasing significantly downstream to reaches D and E. Across all sites the sediment nutrient levels were substantially lower than in 2006. The relatively higher levels of soil nutrients at reaches B and C may be related to higher levels of Phragmites growth and litter formation.

- Growth conditions: Strongest conditions for Phragmites growth were at the upper sites, particularly reaches B and C. At these reaches the soil physical properties are more suited to plant growth and nutrient availability is relatively higher such that N-limitation (and potential P-limitation) is less pronounced. These better growth conditions are reflected in the standing biomass, particularly at reach C. Based on root reserves, reach B would be expected to have Phragmites growth similar to that observed at reach C; the unrealised potential for Phragmites growth at reach B may be due to other factors not investigated in this work.

- The density of Phragmites was generally higher than that observed in 2006 despite the apparently lower availability of nutrients. The areal coverage of Phragmites is however less, so the persistence of Phragmites stands is more likely driven by other hydrologic or land use factors (e.g. fluvial scouring, grazing etc.). The data collected in this study suggests that the nutrient storage in Phragmites stands has decreased since 2006, due to both the decreased areal extent of these stands as well as the lower nutrient inventory (kg/ha) within the stand areas.
- Higher levels of N and P remain within plants and soils within reaches B and C. These higher nutrient levels are believed to be legacy of high nutrient discharges from near Horsham, from wastewater and irrigation drainage discharges particularly up to the 1980's. These levels, although reduced from 2005 levels, remain relatively high. This observation has informed the Wimmera CMA that these nutrients are being bound up in Phragmites and sediments, and are not being flushed downstream, nor decaying as rapidly as was anticipated. High nutrient levels in these reaches are expected to remain in the system for many decades. The harvesting and removal of Phragmites shoot system would be one method of nutrient reduction worth investigating.

Conclusions

The 2019 cover of Phragmites within the Wimmera River channel between Horsham and Lake Hindmarsh has shown a measurable decline in cover since 2005. The use of satellite imagery spectral analysis successfully identified the majority of Phragmites that was clear of overhead tree canopy within the project reach of the Wimmera River. The length of blockages is considered the most accurate and repeatable measure of Phragmites cover and this attribute showed a decrease from 17% of the river length in 2005 to 11% in 2019.

Despite this decrease in cover since 2005, the density of Phragmites, where present, was higher in 2021. Although the climate/weather conditions in the years/months prior to the January 2021 sampling were more favourable than in 2006 (during drought conditions), nutrient levels are measurably lower within plant material and especially lower within sediments. This leads to the inference that the decrease in cover over this 16 year period has been caused by fluvial scour during flooding (i.e. the floods of 2010-2011, 2016), and increased water depths due to environmental flows, rather than being driven by a nutrient deficiency. This has implications for the Wimmera CMA's long-term management and communication of nutrient and Phragmites dynamics for the Wimmera River and highlights the legacy issues brought about by past water management practices.

The results of the mapping and nutrient analysis have implications for the long-term management of reed species in the Wimmera River such as the need to investigate actions like harvesting and (cultural) burning of reeds to expedite nutrient removal from the system. It will better inform environmental water outcome monitoring and target setting for the region given sediment nutrient levels and Phragmites abundance were seen as a proxy for determining the impacts of integrated catchment management activities upstream on reducing nutrient impacts. Finally, it will enable more meaningful discussions with the community around phragmites management given it is seen as a major issue affecting the river's aesthetic appeal and recreational benefits but obviously has an important role in managing nutrient loads and providing habitat for aquatic and bird species.

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