Regular intervention monitoring providing valuable insights into vegetation responses to environmental flows on rivers

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Key Points

- The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) Stage 6 aims to assess the short-term response of vegetation to individual flow events.
- Repeated before and after monitoring at short intervals provides fine scale data to assess riparian and in stream vegetation response to flow regimes through time.
- These fine-scale surveys, coupled with experimental grazing exclosures, highlight the substantial impacts of flows and grazing and their interactions.
- In the absence of heavy grazing pressure, flow regime management can be used to support and regenerate native riparian plant species and exclude terrestrial exotic species from Victorian river channels.
- This paper summarises the conference presentation, providing a brief introduction to VEFMAP Stage 6 and outlining some preliminary observations from the first two years of the program.

Abstract

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was initiated by the Victorian Government in 2005 and is tasked with providing evidence for environmental flow benefits in Victoria. In 2016, the program was revised to provide more detailed evidence of the short-term effects of environmental flows on vegetation and fish. Evaluating the short-term responses of successive flow interventions improves the understanding of causality for responses to longer-term flow regimes. The first two years of this revised program have yielded new and valuable insights into the magnitude and extent of vegetation responses to flow management. Additionally, the updated and vastly expanded communication strategy and participatory nature of the research is allowing for direct input of findings into management of flows and strategies to further improve knowledge. Key results for vegetation responses across Victoria include recording of flow-induced mortality of undesirable species and growth of desirable species, recruitment and survival of different species under inundation and grazing (livestock/rabbit/kangaroo), and the impacts of flows and grazing on native and exotic cover at different bank elevations.

Keywords

Environmental flows, riparian vegetation, monitoring, methods, intervention

Introduction

VEFMAP was established by the Department of Environment, Land, Water and Planning (DELWP) in 2005 to monitor and evaluate the impacts of environmental flows in Victorian rivers. VEFMAP Stages 1-5 included a range of design, data collection, reporting and evaluation outputs and Stage 5 was completed in mid-2016.

Stage 6 of VEFMAP, due to run from 2016-2020, is distinct from previous stages, with many components of the program revised in 2016. While the earlier stages of the program demonstrated the impacts of inundation on terrestrial plant encroachment of river banks, there was limited ability to understand the impacts of environmental flows specifically, or which responses were linked to which flows. Stage 6 objectives for VEFMAP are to improve the understanding of short-term, localised responses of vegetation and fish to environmental flows and to determine how short-term responses accumulate to provide longer-term and broader-scale environmental outcomes. VEFMAP Stage 6 program rationale and design for both the vegetation and fish objectives are summarised in two documents detailing the program framework (Part A) and the program design and methods (Part B; DELWP 2017a, b). Specific objectives for the vegetation component of VEFMAP Stage 6 were developed in collaboration with Catchment Management Authorities (CMAs), with the broad aim to evaluate the effectiveness of environmental water flow delivery plans in achieving vegetation monitoring objectives over the 3-year sampling time frame of the program stage. Stage 6 seeks to identify if vegetation responses to flow management vary within or among rivers and regions in Victoria, and to assess if vegetation responses to flow management are dependent on, or enhanced by, complementary management interventions (e.g. livestock exclusion).

Environmental flows come in a variety of forms and it is important to deliver the right type of flows at the right time for a specific river in order to maximise net benefits for environmental values (Greet et al. 2012). Different types of environmental flows result in different vegetation responses; some responses are rapid, while others may not be realised for many months or years after a particular flow event. Each flow event has the potential to be beneficial or detrimental to vegetation, depending on when and how it is delivered. For example, it is well understood that mature riparian vegetation often benefits from some inundation, while inundating a plant for too long will drown it (Miller et al. 2013). In addition, while flows are beneficial for transporting seeds and stimulating germination at particular times in the growing season (Greet et al. 2012), very young seedlings are easily killed by inundation (Miller et al. 2013). However, the balance between flows promoting germination and consequently reducing survival is not yet fully understood (Miller et al. 2013).

VEFMAP Stage 6 assessments focus on vegetation that is directly impacted by changing river heights (i.e. fringing and instream riparian vegetation), and for which a suitable flow regime is critical to survival. Fringing and instream vegetation play a crucial role in bank stability, nutrient and temperature regulation, and as a source of food and habitat (Naiman and Decamps 1997, Mac Nally et al. 2008, Webb and Erskine 2003). During Stage 6, the focus is on the response of vegetation to individual short-term flow events (e.g. freshes), and how a series of flow events (the flow regime) can be used to achieve long-term benefits for vegetation.

Regulation of waterways and the reduction of flooding frequency and volumes leads to invasion of banks by terrestrial species, which are usually exotic understorey species (Catford et al. 2014, Greet et al. 2012, Greet et al. 2013, Poff et al. 2010 and Webb et al. 2015). These shifts are likely to alter the composition of species occurring within the channel, which may have significant implications for altered in-channel ecosystem services or functions (Laliberté et al. 2010, Merritt et al. 2010). While river regulation alters vegetation composition, it is anticipated that controlled flow deliveries can be used to favour native riparian species and reduce invasion of undesirable species (Miller et al. 2013).

Nearing the end of the first two years of the VEFMAP Stage 6 study, the results and observations are providing valuable insights into vegetation responses to flows (natural, consumptive and environmental) in Victorian rivers. Given the clarity of these early results, there are clear opportunities for waterway managers to begin incorporating the learnings into flow decisions, as well as to provide feedback to maximise the outcomes of the study in its second half. Here, we present a subset of the preliminary observations from the program to date that address some of the core objectives.

Methods

The VEFMAP Stage 6 methods so far have included broad-scale vegetation mapping surveys using a variety of GPS technologies and Unmanned Aerial Vehicles (UAV), fine-scale quantitative transect surveys, tree canopy cover assessments, grazing exclosure experiments, vegetation planting experiments, soil moisture and in-stream hydrology assessments. The vegetation survey methods used in VEFMAP Stage 6 are described in full in VEFMAP Stage 6 Part B: Program design and monitoring methods (DELWP 2017b) and only a subset of methods are summarised here.

Survey timing

Three surveys are conducted at each site in each water year (financial year). The surveys roughly correspond to spring, summer and autumn timing and all surveys for a single sampling period were conducted within a week. Specific sampling timing is designed so that surveys will be conducted less than three weeks before a planned flow delivery (e.g. fresh or high flow) and two to twelve weeks after the event depending on the flow regime. A longer delay after the event provides enough time for germinants to emerge and be mature enough for identification but is not always possible. An example of survey timing in relation to season and flow discharge is provided below for the Campaspe River (Figure 1). Some of these flows are natural events, some are environmental flow events and others are managed flows for consumption. Data analyses will be conducted to compare across all flows and between different types of flows where appropriate.

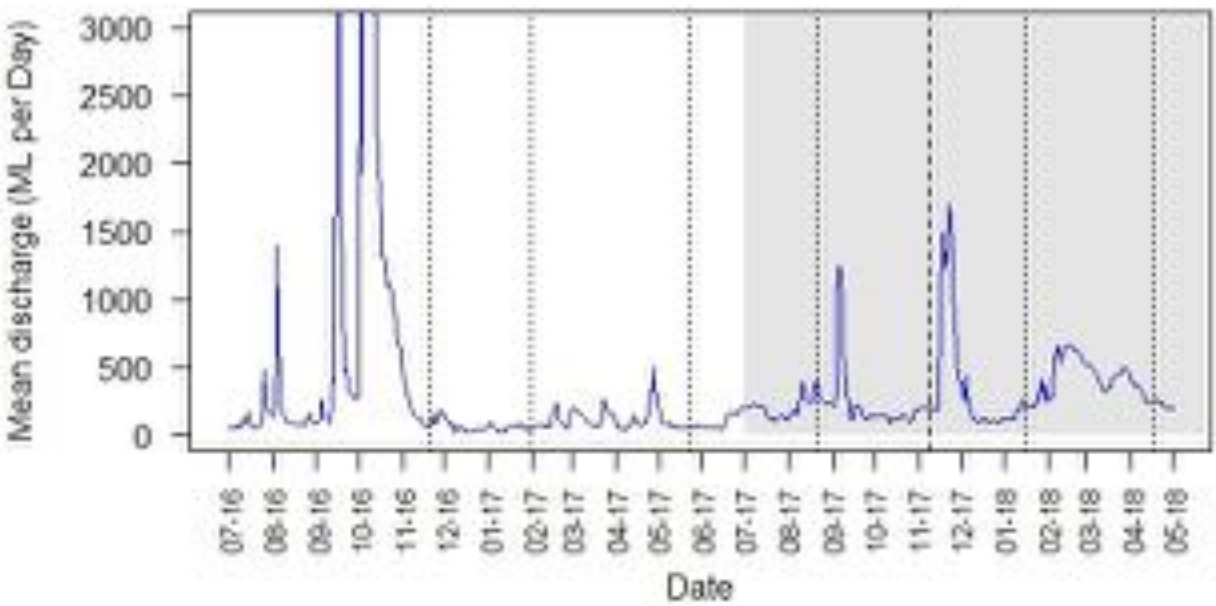

Figure 1. Flow discharge (ML/day) on the Campaspe River (Vic.) recorded at Rochester from July 2016 to May 2018. Vertical dotted lines indicate VEFMAP Stage 6 vegetation surveys. The dashed vertical line indicates an additional survey at a single site only. The white part of the graph is 2016/17, while grey is 2017/18.

Survey locations

Four river systems have been surveyed in the first two years of the program: Campaspe, Wimmera, Loddon and Moorabool. The Campaspe River was the only system surveyed in 2016/17 for the initial pilot study and will therefore have the longest survey period of three years across the full Stage 6 assessment period. Northern Victorian rivers were prioritised at the start of the program with more southern rivers to be added in 2018/19. Future surveys will include resurveys of some systems and surveys of new river systems.

Survey methods

Fine-scale assessments

Fine-scale transect surveys are used to measure the expansion/contraction of existing plant species or groups of plants, as well as the recruitment of new individuals. The methods used are modified from those currently used in the Commonwealth Environmental Water Office (CEWO) Long-Term Intervention Monitoring (LTIM) program (Hale et al. 2014). There are three types of sampling units for the fine-scale surveys: transects, sub-transects and quadrats. The different units (sub-transects: cover and quadrats: recruitment counts) were chosen to appropriately sample different vegetation attributes. The layout of these units is shown in Figure 2. There are four to six sites per river system with ten transects per site. Each site is 200-500 m long depending on the stream shape and accessibility. In a few cases, additional sites were added but with only five transects to expand the spatial distribution of sites, e.g. Wimmera; full details are provided in annual program reports.

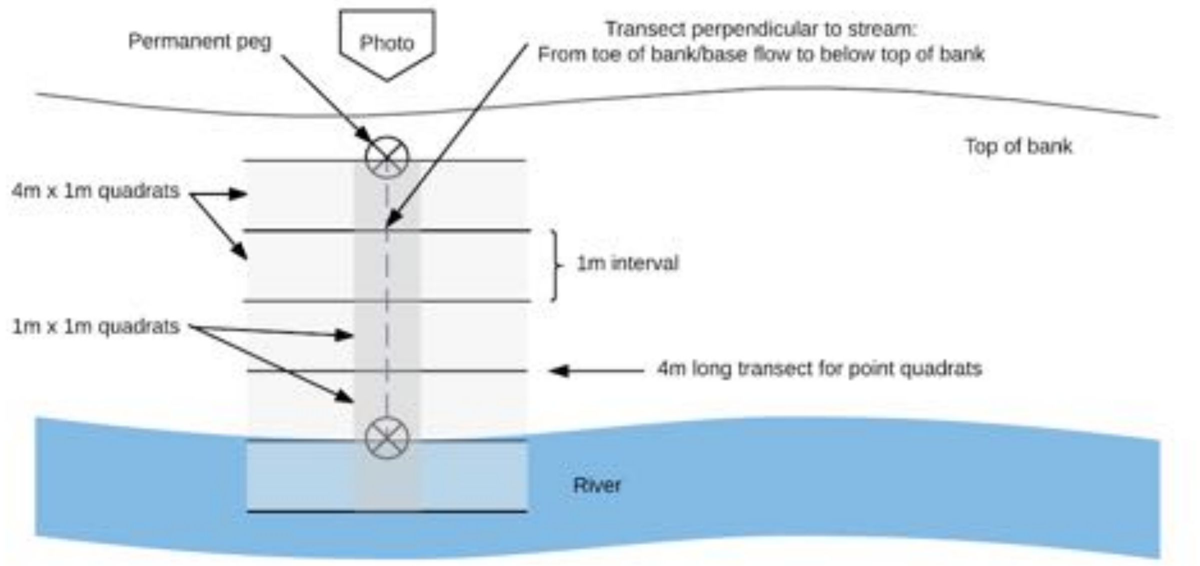

Figure 2. The fine-scale survey method used for VEFMAP Stage 6. Five or ten transects perpendicular to the stream direction are located in representative positions within a site. The number of sub-transects along the five or ten primary transects varies depending on the bank height and slope at that location.

Hydrology and environmental flow delivery

The primary data for the hydrological surveys is flow height (i.e. elevation up the bank) and the duration of that height change. These data are used to evaluate vegetation responses to flows at different locations up the bank gradient, by comparing positions that did or didn't get inundated, as well as the depth and duration of inundation at different locations up the river bank. We use a combination of modelled data and in-stream data loggers obtain flow variables.

Data analysis

Data analysis will be required for all components of the monitoring completed in Stage 6. In some cases, the analysis will be simple and include preliminary analyses that produce relevant and accessible summary statistics that can be used to communicate the findings of the monitoring to a broad audience. In other cases, more detailed analysis methods will be required. VEFMAP Stage 6 is currently in the midst of the data collection, so this paper focuses on preliminary observational results, rather than detailed statistical analysis.

Results and discussion

Here, the results from the first two years of VEFMAP Stage 6 have been summarised into key responses of growth and mortality of inundated vegetation, recruitment, and influences of grazing. For this conference presentation we present initial results, as full statistical analysis is currently in development.

Growth and mortality of inundated vegetation

While some species are tolerant of inundation, many species are not and are quickly killed by total inundation. Monitoring before and after individual flow events has shown which flows cause mortality in particular species. The species most quickly killed by flow events are exotic pasture grasses and herbs that are less tolerant of inundation (Catford et al. 2011, Greet et al. 2013). More tolerant exotic and native species persisted through the same inundation events that were long enough to kill terrestrial species. Two examples of flow-induced mortality are shown in Figure 3 A (Campaspe River) and B (Moorabool River), where a clear line in the bank vegetation is created where inundation intolerant species are killed below that line. Given that the least tolerant species are mostly exotic species and the tolerant species are mostly native, there is a great opportunity to use flows to remove exotic species from parts of the river bank that can be reached by environmental flows. Determining the specific inundation tolerances of different species is being achieved through these field surveys as well as controlled experiments currently underway.

Large patches of inundation intolerant species on waterways are a potential problem because of the likelihood of the entire patch being killed by a large natural flow event. Vegetation patches dominated by inundation tolerant species will be more resilient to flow events, ensuring that the functions they provide (e.g. habitat and bank stabilisation) are also more resilient.

Riparian species may benefit from managed flows in unseasonal dry periods in the absence of other water, depending on when and how the flows are delivered (Greet et al. 2013). A clear gradient of inundation preference and tolerance is shown on the Moorabool River in Figure 3C, from aquatic species up to terrestrial species up the bank resulting from increasing frequency and duration of inundation. Waterways that have a consistent flow level (e.g. the Loddon River, Figure 3D) have a clear demarcation of vegetation where species with particular inundation preferences dominate narrow niches.

Figure 3. Impacts of plant inundation on vegetation type and distribution at different elevations up the river bank (A) large natural flow event on the Campaspe River killing plants intolerant of inundation below the peak flow level, (B) a spring fresh event on the Moorabool River killing plants intolerant of inundation below the peak flow level, (C) clear vegetation stratification on the banks of the Moorabool River, and (D) clear vegetation stratification on the banks of the Loddon River under a stable flow regime.

Plant recruitment and grazing influence

Riparian vegetation is vulnerable to inundation and grazing. Plants are vulnerable to both these disturbances and young seedlings are typically less tolerant than mature plants. Waterway managers often hold concerns that environmental flow deliveries after recruitment may kill young native seedlings. Likewise, for more mature plants, too much water may drown mature plants or too little may result in stress. Grazing exclosures are used in some VEFMAP Stage 6 sites to account for vegetation responses to flows in the presence or absence of grazing. Exclosures were installed at two of the six monitoring sites on the Campaspe River (2 exclosures per site) in 2016, and an additional site (two exclosures) in 2017, and were designed to exclude all livestock, macropods and rabbits (but not birds). The six fenced areas varied in shape to accommodate the shape and contours of the bank at each site but are approximately 50 m^2 in area. Additional exclosures will be installed at grazed sites on other rivers where practical.

Recruitment is required to maintain healthy plant populations. When is occurs, it is most obvious in open channel surfaces (bare ground). Vegetation gaps can be created by disturbance (e.g. flow, grazing) or following deposition of sediments during flow events. One example is shown in Figure 4 where an unoccupied sandbar on the Campaspe River was fenced from grazing at the start of Stage 6 surveys in November 2016 (Figure 4A).

The sandbar was inundated repeatedly following fencing, with recruitment of shrubs, graminoids and herbs recorded over the following months. In particular, hundreds of *Persicaria* spp. seedlings recruited over winter in 2017 and were recorded as new germinants in the August 2017 survey prior to a September fresh (see Figure 1). The very young seedlings survived the September fresh and had reached a few centimetres in height by October 2017 (Figure 4B) prior to a larger November fresh (Figure 1). The intermediate seedlings also survived the November inundation and were well established by the following January (Figure 4C). This cohort of plants flowered prolifically by April 2018 (Figure 4D). However, not all recruited species survived these events and we are now compiling the data to explore which species recruits survive each flow event (or series of events) and how this is impacted by the presence or absence of grazing and the type of livestock species present.

Livestock grazing pressure (cattle and sheep) was light in 2016/17 at this site, but it increased in 2017/18 resulting in a substantial difference between the inside and outside of the exclosure (Figure 4D). The other two sites with exclosures on the Campaspe River (not shown here) have different livestock species present (one with sheep and one with cattle). Although the number of animals present and the duration of grazing access are important factors regardless of which species is present, there are significant differences in impacts between the two species. The largest difference observed was the impact below the waterline, since cattle were very happy to get into the water and their heavy bodies have large impacts on the soft ground, while sheep tended to stay above the waterline.

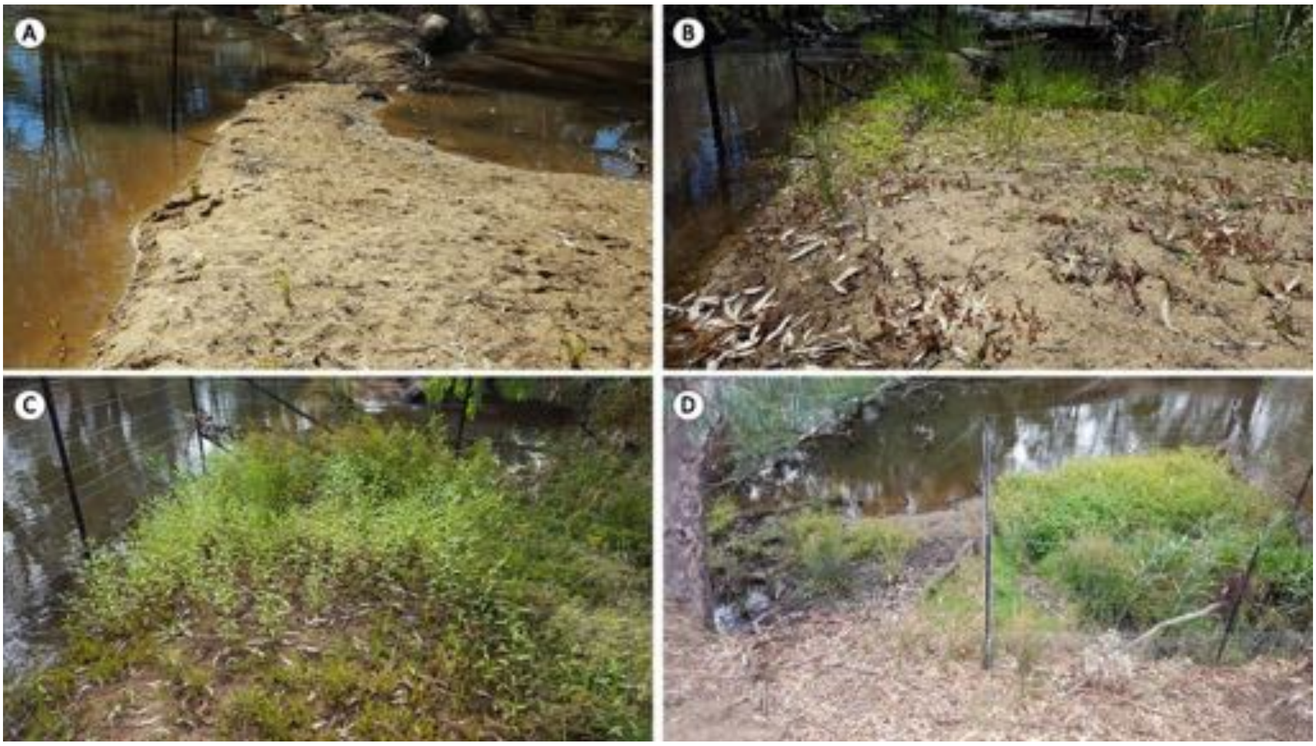

Figure 4. Recruitment of fringing species (particularly *Persicaria* spp.) within a grazing exclosure on the Campaspe River from November 2016 (A) to April 2018 (D). The photo in image A was taken on the same day as the exclosure was installed.

An example from a different site on the Campaspe River with sheep grazing only is used below to show detailed survey comparisons between the area inside exclosures and those immediately adjacent to them following exclusion. Figure 5 shows the similar native and exotic vegetation cover inside and outside of the exclosure in November just prior to the exclosures being installed, followed by a rapid increase in native vegetation through the growing season to May. In contrast, exotic vegetation had a far more modest increase, dominated by two inundation tolerant species (*Panicum coloratum* and *Phyla canescens*). Plant growth receded slightly over winter to August before increasing again over the second growing season. On these lower parts of the river bank, inundation helps to maintain native plant dominance as the vegetation recovers, whereas areas around the top of the bank are dominated by exotic terrestrial species. Using data from these exclosures we can separate the effects of flows and grazing through time.

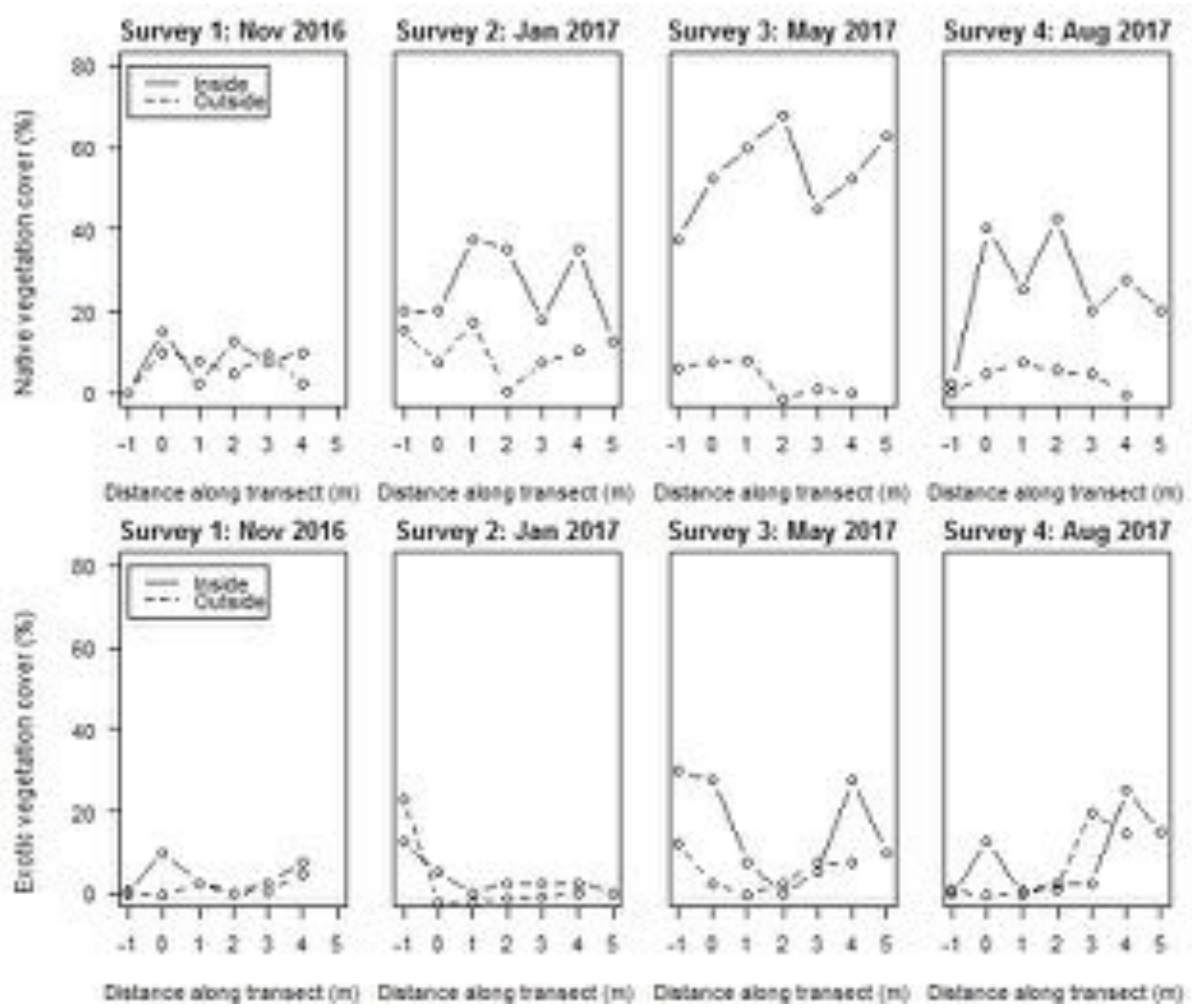

Figure 5. Vegetation cover on the transects inside and outside of a single grazing exclosure over four survey periods in 2016/17. Survey periods in relation to flows shown in Figure 1.

Conclusions

Conducting surveys before and after flow interventions, and successive flows (or periods with no inundation), is providing critical detail for understanding how flow events and regimes influence riparian vegetation. Delivering environmental flows at the right time and for a sufficient duration can be used to reduce exotic species abundance and cover significantly, as well as supporting regeneration of riparian species. Grazing exclusion across all four exclosures installed in 2016 significantly increased reestablishment of vegetation on the river bank, while the two newly established exclosures in 2017 were showing early signs of change. Coupling flows with grazing exclusion will help ensure that regeneration is dominated by riparian species – in most cases native. Additional program components assessing soil moisture and experimentation for plant inundation tolerance will support the field vegetation data to shed light on some of the thresholds that will help guide future management of environmental flows in regulated systems. The ultimate aim of environmental flow management is to support healthy, productive waterways in the long term – but small steps are required to achieve this long-term objective. Understanding the short-term responses and how they accumulate to provide long-term benefits is the key to successful waterway management.

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