Using voluntary agreements to exclude stock from waterways: an evaluation of project success and persistence.

KEYWORDS

Stock exclusion, condition assessment, maintenance, voluntary agreements, river restoration

ABSTRACT

Agriculture is one of the major drivers of ecological degradation in river basins. Excluding stock (cows and sheep) from grazing riverbanks, and accessing rivers, is one of the most common river restoration activities. To be effective, stock exclusion must be maintained indefinitely. In Australia, and elsewhere, stock exclusion projects are most commonly implemented by establishing voluntary agreements between landholders and government agencies. This study examined: the extent to which landholders in three catchment management authority (CMA) regions in south east Australia maintain stock exclusion from waterways, whether vegetation on riverbanks recovered, and the effectiveness of assessment methods. It was found that nearly half of landholders continue to graze stock on the riverbank. There has been some success with improving the condition of riparian vegetation. Sites with full stock exclusion contain the pre-European abundance of juvenile trees, and, sites with continued grazing contain significantly lower abundance of juvenile trees. Establishing the effectiveness of management was made more difficult by the inconsistent methods used by the different CMAs. Stock exclusion projects implemented using voluntary agreements have the potential to succeed if overseeing is improved between government agencies and CMAs, and between CMAs and landholders. Projects will be easier to assess if regional authorities use consistent methods of assessment. Voluntary agreements are only

suitable for environmental management if projects are monitored, maintained, and assessed appropriately.

INTRODUCTION

Agricultural practices are one of the central causes of ecological degradation in river basins (Suding 2011). Over the last 30 years improving the condition of degraded riverine ecosystems has become a central goal of river management, and a widespread area of scientific research (Bernhardt et al. 2007). One focus has been on assessing the impact of the agricultural sector on ecosystems, and designing evidence-based interventions to mitigate further damage. Common river restoration interventions include establishing fishways on dams to restore fish populations, revegetating river basins for gully control, and excluding stock from grazing riverbanks to improve riparian vegetation (Moore & Rutherfurd, 2017). Ideally, these projects should follow the principles of adaptive management (Koehn et al. 2001; Newson 2008); design, implementation, maintenance, monitoring and assessment, whereby the outcomes of assessment inform the next stages of design, and so forth (Rutherfurd et a. 2000) (Figure 1).

------------------------Figure 1 about here---

In practice, the agencies responsible for river management, including government authorities and private institutions, often neglect project, monitoring and assessment (e.g., Bernhardt et al. 2007; Brookes & Lake 2007; Palmer et al. 2005; Palmer et al. 2014). By comparison, the problem of project maintenance is only now being considered (Moore & Rutherfurd 2017). Moore and Rutherfurd (2017) suggest that to be successful, many river restoration projects must be maintained indefinitely, and this is the case for stock exclusion projects. However, academic researchers and river management agencies tend to focus on design and implementation of these projects, rather than assessing how well interventions are maintained (e.g., Department of Environment Land Water and Planning (DELWP) 2015). This paper explores how well one common type of river restoration project (excluding stock from grazing riparian areas) has been maintained and assessed.

In Australia (Brooks & Lake 2007), North America (Bernhardt et al. 2007), and the United Kingdom (River Restoration Centre 2018), fencing along waterways to exclude stock, is one of the most common type of river restoration project. However, these projects are rarely monitored or assessed, and assessment methods are often inadequate, as demonstrated by the study conducted by Ede (2011). As a result, very little is known about whether landholders maintain stock exclusion over the long-term, or if these projects achieve the intended ecological objectives. In short, it is unclear how well scientific knowledge translates into effective environmental management (Bernhardt et al. 2007).

This study investigated stock exclusion projects in Victoria, Australia, including whether projects are maintained, the condition of riparian vegetation, and how effectively regional authorities conduct assessment and monitoring. Over the last three decades more than 10,000 km of stock exclusion fencing has been constructed in Victoria through the establishment of voluntary agreements between regional catchment management authorities (CMAs) and landholders (P. Vollebergh, DELWP, personal communication, February 5th, 2017). Voluntary agreements are contracts that stipulate the terms of stock exclusion projects, including funding and maintenance. The contracts specify that government agencies subsidize the construction of fences, and revegetation of the riverbank with native species, while landholders are legally required to maintain fences, manage weeds in the fenced areas, and exclude stock from grazing riparian areas indefinitely (DSE 2011; Moore & Rutherfurd 2017).

Importantly, similar voluntary arrangements are used to implement a variety of environmental projects elsewhere, including stock exclusion and habitat enhancement in the

United Kingdom (UK) (Rural Repayments Agency 2018), and North America (Bernhardt et al. 2007). Many of these projects have involved government grants for landholders to construct fences for stock exclusion, such as the UK Nature's Wildlife Enhancement Scheme Agreements (Smith & Rushton 1994; Smith et al. 2003).We are aware of only one study that has assessed the effectiveness of government-funded stock exclusion projects, or whether landholders maintain projects (Ede, 2011), and this study was also conducted in Victoria, Australia. Ede (2011) investigated 129 stock exclusion projects in Victoria and concluded that 92% of landholders continue to exclude stock. However, the only landholders evaluated were those who had volunteered their projects for evaluation. Landholders who had not maintained their frontages would be unlikely to volunteer. Thus, Ede's (2011) sample was unrepresentative. Further, the study assumed that intact fences meant that landholders did not allow stock access, which might not be the case. Given that stock exclusion projects implemented using voluntary arrangements with landholders are one of the most common river restoration interventions, further research is justified.

We undertook our research in conjunction with three catchment management authorities (CMAs) in Victoria who conducted the first regional assessments of stock exclusion projects (note that the CMAs are deidentified throughout this paper in order to maintain anonymity, so we refer to them as CMAs A, B, and C). Staff from the three CMAs collected data about the condition of fences, evidence of continued grazing, and the condition of vegetation. Measures of vegetation condition included the abundance of overall native vegetation, native juvenile trees, and invasive species. Importantly, each CMA used different measures and methods of data collection. Thus, our hypotheses vary between study regions. We focus on three research questions. Firstly, we examined how well landholders maintain stock exclusion projects. Few studies consider whether landholders continue to maintain environmental projects over the long-term. One exception is research conducted in association with the United States

Department of Agriculture that emphasized the inhibiting cost of fence maintenance (Hafner & Brittingham 1993; Platts 1982; Platts & Nelson 1985; Platts & Wagstaff 1984; Reichard 1989). However, the problem of maintenance was identified retrospectively, rather than prospectively or experimentally. In contrast, Ede (2011) conducted 129 field assessments of stock exclusion sites in Victoria and concluded that effective stock exclusion was observed at 92% of sites. However, most stock exclusion fences contain gates. Thus, we tested whether fence condition was a good surrogate for stock exclusion, and hypothesized that there would be no relationship between the condition of fencing and a separate measure of evidence of stock grazing in the riparian area. We also examined whether those landholders that continue to graze follow key recommendations outlined in the Victorian grazing guidelines (DEPI 2013; DELWP 2016), including the recommendation to exclude stock entirely for 3-5 years following revegetation, and excluding stock in spring and early summer. Further, we investigated whether grazing has ceased on sites with less than or up to 25% native vegetation cover, as stipulated in the Victorian grazing guidelines. However, the data varied considerably between CMAs, and analysis of sites with less than or up to 25% vegetation cover was only possible on sites in CMA A.

The second research question we addressed was whether stock exclusion is associated with an improvement in the condition of riparian vegetation, including the abundance of native vegetation, juvenile trees, and invasive vegetation. Riparian grazing reduces the abundance of native vegetation on riverbanks, particularly during summer and dry periods (e.g., Fleischner 1994). In contrast, stock exclusion increases the abundance of native vegetation on riverbanks (e.g., Hough-Snee et al. 2013; Miller et al. 2010; Schulz & Leininger 1990). Thus, we hypothesized that sites with complete exclusion would contain a greater abundance of native vegetation compared to sites with continued grazing.

Grazing destroys seedlings before they can mature into canopy trees (Fleischner 1994), while stock exclusion increases the abundance of juvenile native trees (Robertson & Rowling 2000). Ede (2011) found that 52% of fenced riparian areas examined contained between 1-5% coverage of juvenile trees. The abundance of juvenile trees was ranked on a scale of one to five whereby the value of one represented 0% coverage, the value of two represented <1% coverage, the value of three represented 1-5% coverage, the value of four represented 6-25% coverage, and the value of five represented >25% coverage (Ede 2011). Importantly, these categories do not reflect distinctions outlined in the Victorian Ecological Vegetation Condition (EVCs) assessment guidelines; the pre-European baseline coverage of juvenile trees on riverbanks in Victoria is 5%. Thus, it is impossible to determine the number of sites that meet the baseline condition. We hypothesized that sites with full exclusion would contain a greater abundance of juvenile trees compared to sites with continued grazing (Robertson & Rowling 2000), and further that sites with exclusion would meet the EVC baseline of 5% coverage, while sites with grazing would contain less than 5% coverage.

Without effective weed management, stock exclusion sites can contain more weeds than grazed sites (Lunt et al. 2007; Morris & Reich 2013). Grazing reduces the abundance of all vegetation, including invasive species (Morris & Reich 2013). Thus, in the absence of grazing, the amount of weeds could increase. However, landholders involved in stock exclusion projects in Victoria are required to manage weeds after the cessation of grazing (DSE 2011). Thus, we hypothesized that all sites examined in our study would contain a low abundance of invasive vegetation, and that there would be no difference between grazed sites and sites with stock excluded from grazing the riverbank.

The third research question considered the quality of data collected by CMAs. It is widely acknowledged that lack of monitoring and assessment is a problem for river restoration projects (e.g., Bernhardt et al. 2007; Brookes & Lake 2007; Kondolf et al 2007; Lave 2018, Palmer et al. 2005 2014). For example, the Victorian Catchment Management Council (VCMC) conducts five-yearly reviews of all available data from the ten Victorian CMAs about the state-wide condition of catchments, including the condition of riparian vegetation on river restoration sites (VCMC 2017). The 2012 VCMC review emphasized the inadequacy of condition assessment data across the state. The publication prompted an investigation by the Victorian Auditor-General into the effectiveness of the CMAs (Victorian Auditor-General 2014). The audit report acknowledged the substantial limitations of existing data, and the need to improve arrangements for monitoring and assessment of catchment condition. Thus, in 2013 the CMAs began to assess the condition and outcomes of government funded stock exclusion projects.

We examined whether the data would allow us to test hypotheses about whether stock exclusion improves the condition of riparian vegetation. We also considered the usefulness of the data in relation to the five-yearly reviews conducted by the VCMC. The VCMC reports about the state-wide condition of catchments in Victoria (VCMC 2017). This process requires that data are comparable between regions. Thus, we explored whether the data from three regions could be meaningfully compared to gain a state-wide overview of the success of riparian restoration projects. The research aims and hypotheses outlined above are summarised in the following.

RESEARCH AIMS AND HYPOTHESES

There were three purposes of the research. The first purpose was to determine how many landholders continue to graze in riparian areas after the establishment of fencing, compared to those that have excluded stock entirely. We also examined whether those landholders that continue to graze follow the Victorian grazing guidelines (DELWP 2016). The second purpose of the research was to investigate whether stock exclusion is associated with an improved condition of riparian vegetation. We tested seven hypotheses about the relationship between stock exclusion and vegetation condition. These hypotheses, and the statistical data analysis methods, are summarized in Table 1.

-------------------------------Table 1 about here---

The third purpose of the research was to investigate the quality of data collected by CMA staff, and thus, whether CMA methods of assessing stock exclusion are effective. We considered whether the available data from three CMAs were sufficient for determining the ecological outcomes of stock exclusion projects, and whether the data collected by the three CMAs were comparable.

METHODS

Participants & procedure

The participants were 231 landholders from three, predominately agricultural, regions in northern Victoria: CMA A (n = 137), CMA B (n = 50), and CMA C (n = 50). Landholder involvement in stock exclusion projects varied from 2 to 10 years prior to assessment. Little data were available about the age of each project. All 231 landholder properties were visited for evaluation by CMA staff members. The average age of landholders was 55 years old, and more than 80% were male. Participant property sizes ranged between 200 and 3,000 hectares. Figure 2 indicates that the main farming activities were keeping stock, including cattle and sheep, and mixed agriculture, including cropping, horticulture, and stock fodder. Most farmers in CMA B were graziers while the majority of farmers in CMA A and CMA C practiced multiple farming activities.

--Figure 2 about here--

Data about evidence of grazing, fence condition, and vegetation condition, including the abundance of native vegetation, juvenile trees, and invasive species, was collected by CMA staff during these evaluations. In addition, we mailed a social survey to all participants to examine whether landholders who continue to graze follow the Victorian grazing guidelines (VGGs) that were established by the Department of Environment and Primary Industry in 2013 (DEPI 2013; DEWLP 2016). The social survey also included items about the type of farming that landholders practice, and the size of properties. In total, 93 landholders completed and returned usable surveys (40% return rate).

We also analysed gridded daily precipitation data from the Bureau of Meteorology's Australian Water Availability Project (AWAP) dataset (Jones et al 2009) to investigate whether climate might explain any differences of vegetation condition we found between the three CMAs. Daily precipitation was extracted from an AWAP grid cell (0.05° x 0.05°, approximately 5km x 5km) representative of the farm's latitude and longitude for the period 1900-2016. We calculated the average long-term rainfall for each of the 93 study sites, as well as the average of the two years during which the research was conducted (2013-2014), and used ANOVAs to explore any statistical differences between the regions.

Measures

Evidence of stock exclusion or stock grazing

Measures of stock exclusion were recorded by CMA staff during visual inspections, and landholder responses to open-ended questions about grazing practices in the social survey. Field observations recorded by CMA staff included hoof marks, eaten or damaged vegetation, and the presence of stock on riverbanks during the inspection. Three staff from each CMA conducted condition assessments. Staff underwent internal training to standardize assessment methods within each CMA. Thus, slightly different methods were used between each CMA.

We obtained information about whether landholder grazing regimes uphold the VGGs from the sub-sample of 93 landholders who completed our social survey. Vegetation data (described below) and survey data were used to investigate whether landholders who continue to graze do so in accordance with the Victorian grazing guidelines. In 2013 the Victorian Department of Environment and Primary Industry published guidelines for managing grazing on riparian land (DEPI 2013). A revised edition was published in 2016 by the now Department of Environment, Land, Water, and Planning. These guidelines were introduced to restrict grazing to sites that are unlikely to be altered by the presence of stock on riverbanks. Grazing of short-duration (‘crash’ grazing) is permitted to control invasive pasture grasses that would otherwise out-compete planted or self-sown native seedlings (DELWP 2016). Our study investigated whether current grazing regimes reflect key recommendations stipulated in the Victorian grazing guidelines, including the following:

- Stock should be excluded from riverbanks in spring and early summer when native species typically germinate;
- Stock should be excluded from revegetation areas for 3-5 years to allow native vegetation to establish;
- Grazing should not be permitted on sites with less than or equal to 25% vegetation cover

The social survey included two items about grazing regimes. The first item asked landholders to report how many years following the completion of the restoration project that grazing commenced. The second item asked about the time of year, including the seasons and months, that grazing occurs. The data were used to investigate whether grazing regimes reflect the first two recommendations outlined above.

Fence condition

The condition of fencing was described by CMA staff during site inspections. Observations were recorded including damage to fence wires, and evidence that gates in fences were used for stock access. Each CMA developed a ranking system that indicated whether fencing effectively excluded stock from the riverbank, or if stock were able to access the riverbank. For example, CMA A classed fence condition as ‘good’, ‘medium’, or ‘poor’, whereby fences in ‘good’ condition effectively exclude stock, and those in ‘medium’ or ‘poor’ condition permit stock access to varying degrees. We standardized fence condition data from the three CMA regions into two categories: ‘good’ fencing successfully excludes stock while ‘poor’ fencing permits stock access to riverbanks.

Vegetation condition

The relationship between stock exclusion and vegetation condition was assessed by the abundance of: native vegetation, juvenile trees, and invasive species. However, the quality of vegetation condition data collected by the three CMAs varied considerably. CMA A and CMA C used standardised state-wide data collection procedures, while CMA B used a method devised by regional staff. Staff from CMA B conducted a visual assessment of riverbanks and classified vegetation condition as ‘good’, ‘medium’, or ‘poor’. These data did not include measures of vegetation features or the abundance of native and invasive vegetation. Therefore, we excluded vegetation data from CMA B from our analysis. The assessment method, and vegetation measures for each CMA are summarized in Table 2.

CMA A

CMA A used an assessment method consistent with the methods outlined in the Victorian Ecological Vegetation Classes (EVC) guidelines (DSE 2004). This method involved walking the riverbank for up to 100m along the length of the fenced riverbank and recording observations about the abundance of vegetation observed at each site on a continuous scale, between 0% and 100%. The EVC classes provides a benchmark for setting restoration goals and assessing projects (Parkes et al. 2003). We compared vegetation condition data from CMA A to the predicted pre-European vegetation species distributions (known as Ecological Vegetation Classes). For example, the most common EVCs of sites in the study regions were Floodplain Riparian Woodland, Riparian Forest, Riverine Grassy Woodland, and Box Ironbark Forest (DELWP 2017). These EVCs stipulate that the pre-European vegetation had a benchmark of 5% juvenile tree cover, whereby juvenile tree cover refers to the percentage of area covered by the foliage of individual canopy plants, taller than 0.3m but below 5 metres (DSE 2004). Therefore, we anticipated that sites in CMA A with continued grazing would have less than 5% juvenile tree cover than sites with continued grazing.

In accordance with the EVC guidelines, total native vegetation cover is classified as 'absent' if less than 10% cover is observed, 'few' if between 10% and 50% cover is observed, and 'abundant' if more than 50% cover is observed. Total invasive species cover is classified as 'low cover' if between 5% and 25% cover is present, 'easily observable' if between 25% and 50% is present, and 'visually dominant' if more than 50% cover is present. The total native vegetation cover of riparian areas was a measure of the highest percentage of cover of each of native grasses, shrubs, juvenile trees, and mature trees. These data were used to examine the relationship between native vegetation cover and stock exclusion, and to investigate whether grazing is excluded from sites with less than or equal to 25% native vegetation cover are, as per the Victorian grazing guidelines.

<u>CMA C</u>

In contrast to CMA A, staff from CMA C followed a' rapid assessment' method to assess vegetation condition. Staff walked the length of the riverbank for one hundred meters and recorded observations about vegetation condition. The abundance of juvenile trees and invasive species was classified on a categorical scale of one to five, rather than on a continuous scale of between 0% and 100%. The value of one is equal to no regeneration, two is equal to less than 1% ground cover, three is equal to up to 10% ground cover, four is equal to between 10% and 30% groundcover, and the value of five is equal to abundant regrowth of more than 30% regeneration.

The abundance of invasive vegetation was also classified on a categorical scale of one to five, whereby the value of one indicates that no invasive vegetation is present, the value of two indicates that less than 10% of the riverbank is covered with invasive species, the value of three indicates that between 10% and 40% is covered, the value of four indicates that between 40% and 60% is covered, and the value of two indicates that more than 60% of the riverbank is covered. We used this categorical data to examine the relationship between stock exclusion, and the abundance of juvenile trees and invasive species on sites in CMA C.

-------------------------------------Table 2 about here---

The quality of vegetation data were also central to our analysis of the condition assessment methods employed by each CMA. We examined whether it would be possible to compare vegetation condition data to EVC benchmarks, as stipulated by the Victorian EVC guidelines (DSE, 2004), and whether it was possible to compare data between the three CMAs.

RESULTS

The assessment of riparian restoration projects conducted by CMA staff across three regions included the evaluation of 231 landholder properties. However, the evaluation data indicated that some properties no longer run cattle, while others do not currently have riverbank fencing. Therefore, the sample size varies for the statistical analyses used to test each hypothesis, as described below.

Figure 3 suggests that the annual average rainfall varies considerably between regions. ANOVA confirmed that there was a significant difference between the three regions for the long-term average rainfall, and the average rainfall of the two years during which the research was conducted (2013-2014). The long-term average rainfall of CMA B (*M* = 1030.28, *SD* = 216.16) was significantly higher than the long-term average of CMA A (*M* = 405.93, *SD* = 50.48) and CMA C (*M* = 764.73, *SD* = 229.86), F (2, 78), = 3.12, p = .00. Similarly, the average rainfall for 2013 and 2014 of CMA B (*M* = 925.20, *SD* = 188.42) was significantly higher than the two-year average of CMA A (*M* = 334.27, *SD* = 29.86) and CMA C (*M* = 652.36, *SD* = 198.29), F (2, 78), = 3.11, p = .00.

-------------------------Figure 3 about here--

In addition, a t-test was computed to investigate whether the average rainfall in all three regions for 2013 and 2014 was different to the long-term average, as suggested by the columns marked ‘total’ in Figure 3. A t-test found that the average rainfall of all 93 landholder properties was significantly lower in 2013 and 2014 (*M* = 742.78, *SD* = 312.12) compared to the long-term average (*M* = 645.22, *SD* = 285.88), t (82) = 2.09, p = 0.02. Thus, rainfall was taken into consideration for interpreting our findings about vegetation condition.

Descriptive results

Grazing practices

The number of sites in CMAs A, B and C where stock were grazed or excluded, and where either the landholders no longer run stock or the data were insufficient to determine stock access, is summarized in Table 3.

---Table 3 about here--

Of the sub-sample of 93 landholders that completed the social survey, 53 (57%) continue to graze restoration sites, and 40 (43%) practice total exclusion of stock from restoration sites. Of those landholders that continue to graze, 41 responded to the survey item asking landholders to report the time of year that grazing occurs. Most landholders graze in spring (N = 14) or summer (N = 17). Two landholders reported grazing all year round, and two landholders reported grazing only when the river is high. Of those that graze, 30 landholders responded to the survey item about the length of time since the establishment of the stock exclusion project after which grazing resumed. Four reported that grazing resumed less than one year after the establishment of stock exclusion projects, half reported that grazing resumed less than three years after, and the remainder reported that grazing resumed more than three years after.

Vegetation condition

Table 4 displays the means and standard deviations for measures of vegetation condition from sites in CMA A. Of the 137 site assessments conducted in CMA A, four assessments were missing data related to the coverage of juvenile trees and the total coverage of native vegetation, and ten assessments were missing data related to the total coverage of invasive species. Therefore, the sample sizes vary for these measures (Table 4). The standard deviation of juvenile tree cover shows little variability between sites (*SD* = 7.79), while the standard deviation of native vegetation cover (*SD* = 22.54) and invasive species cover (*SD* = 18.77) shows considerable variability between sites.

The means and standard deviations for measures of vegetation condition from sites in CMA C are also displayed in Table 4. The mean score for juvenile tree cover on sites in CMA C was close to the value of ‘3’ on the categorical scale. Thus, according to the scale, most sites contained 'up to 10% cover'. The standard deviation indicates very little variability (*SD* = 2.66). The mean score for the abundance of invasive species coverage on sites in CMA C indicates that on average, sites in CMA C contain between 10% and 40% coverage. The standard deviation suggests there is little variability (*SD* = 1.13).

-------------------------------------Table 4 about here--

Data from CMA A were analysed to determine if grazing continues on sites with less than or equal to 25% total native vegetation cover. Of the 65 sites that were grazed, 20 contained less than or equal to 25% total native vegetation cover.

Fence condition

Of the 232 site assessments, 30 records were missing data related to fence condition. In total, 70% of sites contained fences in 'good' condition (N = 141) and 30% of sites contained fences in 'poor' condition (N = 61). Further, Chi Square analysis revealed that fence condition varied between the three CMA regions, $\chi^2(2, N=202) = 3.05$, p = .000. Of 118 sites in CMA A, 80% (N = 94) were in good condition. Similarly, of 38 sites in CMA C, 79% (N = 30) were in 'good' condition. By contrast, of 46 sites in CMA B, only 37% (N = 17) were in 'good' condition.

Relationships between grazing, vegetation condition, and fence condition

Hypotheses 1, about the relationship between stock exclusion and fence condition, was supported as there was no relationship between fence condition and grazing, $\chi^2(1, N=124) = .411$, p = .52. Hypothesis 2 was supported as sites in CMA A that were grazed (*M* = 1.68, *SD* = 4.14) contained significantly less juvenile tree cover than sites with full exclusion, (*M* = 4.77, *SD* = 9.87), t (131) = -2.32, p = .02. Hypothesis 3 was partially supported as grazed sites contained less than 5% juvenile tree coverage, and sites with total exclusion contained only marginally less than 5%. Hypothesis 4 was supported as there was no difference in the amount of native species coverage between grazed sites (*M* = 21.69, *SD* = 21.21) and sites with total exclusion (*M* = 23.38, *SD* = 23.83), t (131) = -.43, p = .67. Similarly, Hypothesis 5 was not supported as there no difference in the amount of invasive species coverage between grazed sites (*M* = 25.19, *SD* = 18.13) and sites with total exclusion (*M* = 29.95, *SD* = 19.20), t (125) = -1.44, p = .154.

Hypothesis 6 was not supported as the abundance of juvenile trees was no different between grazed sites (*M* = 2.63, *SD* = .62) in CMA C and sites with total exclusion (*M* = 2.67, *SD* = .88), t (41) = -.17, p = .868. Hypothesis 7 was supported as there was no difference in the abundance of invasive species between grazed sites (*M* = 3.25, *SD* = 0.87) and sites with total exclusion (*M* = 3.39, *SD* = 0.52), t (27) = -0.51, p = 0.31. All sites contained between 10% and 40% coverage of invasive vegetation.

Data quality and the consistency between CMA vegetation measures

The research investigated the effectiveness of vegetation condition assessments from two perspectives; firstly, whether the data were of sufficient quality to determine the influence of stock exclusion projects on vegetation condition, and secondly, whether it was possible to meaningfully compare data between the three CMAs. We found that the quality of vegetation condition data varied considerably between CMAs. We were able to statistically analyse data collected by CMA A and CMA C. The analysis explored whether the abundance of native vegetation, juvenile trees, and invasive vegetation, was different for grazed sites compared to sites with complete stock exclusion. In addition, it was possible to compare data from CMA A against the relevant EVC baselines. However, we were unable to compare data from CMA B or CMA C against baseline conditions.

We also found that it was not possible to compare vegetation data between the three CMAs, or to summarize the overall condition of vegetation across the three regions. Thus, with the exception of the abundance of juvenile trees in CMA A, it is difficult to be definitive about whether stock exclusion projects are effective for improving the condition of degraded riparian vegetation in Victoria.

DISCUSSION

To be effective, many environmental projects, such as stock exclusion, must be monitored, assessed, and maintained indefinitely. We examined data from an evaluation of a common river restoration project; stock exclusion. Here we discuss the main findings, and the implications for improving the success of river restoration more widely.

Maintenance of fences and stock exclusion

Despite that fact that approximately 70% of fences on stock exclusion sites were in ‘good’ condition’, stock grazing continues on nearly half of the sites examined in the research. Ede (2011) assumed that intact fences successfully excluded stock. However, we found that there was no relationship between fence condition and evidence of grazing, suggesting that fence condition alone is not an appropriate proxy for actual stock access to riverbanks. Of the 93 landholders who complete the social survey, 53 continue to graze the fenced frontage. The Victorian grazing guidelines suggest that stock should be excluded from riverbank areas during spring and early summer, and that grazing should cease for between 3 to 5 years after the establishment of restoration sites. Of the 53 landholders that continue to graze, more than half graze in spring and summer. More than half reported that grazing recommenced less than 3 years after the establishment of projects. The grazing guidelines also stipulate that full exclusion should occur on sites with less than 25% total cover of native vegetation. Grazing continues on 65 sites in CMA A, and nearly one third of those sites contain less than 25% total coverage of native vegetation.

To be effective, stock exclusion projects must be maintained indefinitely. These results suggest that landholders who voluntarily adopt environmental practices do not necessarily maintain those practices over the long-term. This could be explained by numerous factors, including whether the terms of voluntary agreements are adequate (in this case, this includes whether the agreements reflect the grazing guidelines), and if the individual landholder chooses to uphold the terms of the agreement. Given that CMA records are incomplete, the exact number of landholders in agreements that predate the grazing guidelines is not known.

Problems related to the establishment and administration of contractual agreements between parties involved in environmental management are not uncommon. Even where the contract is commercial in nature, compliance can be poor. For example, Hallwood (2007) suggests that the failure of 50% of mitigation wetlands in the USA is related to the poor design and implementation of contracts between government agencies and the firms who construct the wetlands. Firms shirk contractual responsibilities, such as maintaining water levels, because their operations are not overseen by regulatory authorities. Thus, Hallwood (2007) concludes, "An un-enforced contract is not worth the paper it is written on." (p.449). Many river restoration projects, including stock exclusion, increasing instream wood loads, and habitat enhancement (E.g., Bernhardt et al. 2007; Gunningham 2003; Rural Payments Agency 2018), involve establishing voluntary opt-in agreements with farmers. It is highly probable that such voluntary agreements will require even more oversight than the robust legal contracts between regulatory authorities and mitigation wetland agencies.

Abundance of vegetation

We hypothesized that sites with stock excluded would contain a greater abundance of native species (e.g., Hough-Snee et al. 2013; Schulz & Leininger 1990). In contrast to the findings of Ede (2011), stock exclusion in CMA A did not increase the amount of native vegetation within the fenced frontage, compared to sites with continued grazing. However, it is likely that two years of below average rainfall reduced the growth of native species. Thus, our data may not reflect the true benefits of stock exclusion for increasing the abundance of native vegetation. In the context of climate change and drought events in Australia, native vegetation may struggle to out-compete invasive species, particularly in the absence of effective weed management (e.g., Morris & Reich 2013).

Consistent with Robertson & Rowling (2000), sites in CMA A with continued grazing contained less cover of juvenile trees than sites with stock excluded. Grazed sites contained less than half the amount of cover stipulated as the EVC baseline for juvenile trees, while sites with stock excluded contained nearly the baseline amount. This suggests that excluding stock might contribute to an increase in the abundance of juvenile trees.

Sites in CMA C were ranked on a scale of 1 to 5 in relation to juvenile tree coverage. This approach is not dissimilar to the method employed by Ede (2011). In contrast, we found that there was no difference for juvenile tree coverage between sites with stock grazing and sites with stock exclusion in CMA C. This may be due to the fact that our sample size was smaller than Ede's (2011), or that the data rankings may have obscured any genuine differences between grazed and ungrazed sites.

As predicted, there was no relationship between the abundance of weeds and grazing on sites in CMA A and sites in CMA C. All sites in CMA A contained low (between 5% and 25%) abundance of invasive species. All sites in CMA C contained between 10% and 40% abundance of invasive species. This suggests that landholders are performing weed management. The fact that sites in CMA C contain a greater abundance of invasive species compared to sites in CMA A may be related to climate. During 2013 and 2014, CMA A experienced significantly less rainfall than sites in CMA C (Figure 3). Thus, the low amount of invasive vegetation may reflect rainfall rather than the amount of weeding performed by landholders.

Overall, our results suggest that while most landholders maintain fences, approximately half continue some amount of grazing. Thus, fence condition does not reflect stock grazing. Further, with the exception of juvenile trees, there is little relationship between grazing and vegetation. However, this may be because the time between the establishment of projects and assessment varies considerably between sites. Unfortunately, we were unable to obtain exact dates for when each project was established. We know that some projects were established several years ago, while others were established more than a decade ago. Juvenile trees of between 0.3m to 0.6mcm in height can grow within a year of seeding or planting saplings (Di Stefano 2002). Thus, it is possible that not enough time has elapsed since the establishment of some projects to find significant changes in the abundance of native vegetation.

Of note, our results may also be confounded by two years of below average rainfall. Death et al (2015) emphasize the importance of designing river restoration projects in the context of future climate change trajectories, such as extreme flooding that may alter channel morphology and ecology. We suggest that it is equally as important to consider if existing management arrangements are likely to be suitable in the future. Landholders in drought-prone regions (or flood-prone regions) may require additional assistance to maintain environmental projects (Moore et al. 2018).

Effectiveness of condition assessment

This study suggests that poor data quality, and lack of consistency between agencies, are ongoing problems that continue to present challenges for the assessment and management of river restoration projects. Each CMA used different assessment methods. Thus, it is difficult to determine how effective stock exclusion projects are, or the overall condition of riverine ecosystems in Victoria.

These observations demonstrate the importance of linking measures of condition assessment to benchmark targets for vegetation recovery, and highlight a fundamental problem with environmental management that involves multiple tiers of governance (such as between the state departments responsible for publishing guidelines and CMAs): lack of consistency and oversight. Methods of assessment, and the conditions of voluntary agreements should reflect best-practice guidelines. Oversight is required, both in terms of government agencies ensuring CMAs follow consistent methods, and in terms of farmers complying with contracts. Hallwood (2007) comes to similar conclusions about the widespread failure of mitigation wetlands. The United States Environmental Protection Agency provides numerous guidance documents about complying with the requirements for establishing mitigation wetlands (USEPA 2018). However, these guidelines are often not adhered to. Thus, oversight is required to improve compliance, and contracts should include penalties for non-compliance (Hallwood 2007).

Our suspicion is that the problem of inconsistent methods between CMAs in Victoria is related to the transition from regional management systems to a centralized condition assessment system. Prior to the introduction of centralized systems in recent years, including the EVCs and Victorian Grazing Guidelines, the CMAs developed independent methods of implementing and assessing river restoration projects. CMA officers are likely to be concerned that they will lose much of the valuable information that they have collected in the past if it is not consistent with the new centralised approaches. Thus, further research is needed to support the transition to consistent methods of condition assessment that are comparable between regions, while still maintaining the value of existing CMA data. This type of transition from regional to centralized methods of environmental management represents the maturation of the river restoration sector.

Limitations

There are four limitations of this study that may have influenced our data and our findings. Firstly, most agricultural sites have histories related to past land use practices. Past land use can influence the success of current restoration practices. For example, a longer history of grazing prior to the current landholder is likely to make it more difficult to revegetate the riverbank (Belsky et al. 1999). Similarly, the time since stock exclusion, and thus the amount of recovery, varied between sites. Secondly, many stock exclusion projects were established during the recent decade-long drought in Victoria. Reduced rainfall may have reduced vegetation growth (Jansen & Robertson 2001). Thirdly, while most sites included in this study ran cattle, approximately one quarter also ran sheep. Given that sheep have less impact on riverbanks, this is not likely to affect the main outcomes of our study, other than to under-represent the true impact of cattle on riverbanks. Thirdly, evidence of grazing does not always reflect landholder practices. In some cases stock from properties on the other side of the waterway can gain access to restoration sites by crossing the river channel. This is a known issue and one that CMAs are actively addressing. Fourthly, this study does not account for landscape-scale factors, including the availability of upstream seedbanks, and flood regimes.

CONCLUSIONS

The success of environmental projects in river basins depends as much on maintenance and management as it does on designing and implementing appropriate interventions (Moore & Rutherfurd 2017). To be effective, voluntary agreements should stipulate measurable targets, and reinforce strong links between restoration activities, and the ecological processes that are involved for achieving those targets (Danne 2003; Kehoe 2006).

We found that each CMA involved in the research used different vegetation assessment methods. Thus, it was difficult to draw conclusions about the condition of vegetation in Victoria, or the success of stock exclusion projects. Our analysis suggests that voluntary agreements should contain specific terms that are consistent with best practice guidelines, and that policy makers should conduct more effective oversight of contract compliance. Further, we acknowledge that the river restoration industry is in transition, from fragmented approaches to centralized approaches. While this is necessary to effectively evaluate the success of costly projects, there is a need to consider the impact of this transition on regional authorities. The process would benefit from greater participation from, and consultation with, regional authorities.

It appears that there are few incentives for landholders to uphold the terms of their voluntary agreements, and no consequences if they do not do so. This is a common problem with using voluntary agreements to implement environmental projects (e.g., Danne, 2003). Others have suggested that in some circumstances VAs should be more strictly policed (Gunningham, 2003). We suggest this is possible for the VAs considered here. CMAs could require landholders to pay back the cost of fencing, revoke grazing licences, or issue fines. However, using such legal measures may discourage other farmers from entering into voluntary agreements in the future. Thus, while there is a need to develop more effective incentives for compliance, the use of legal instruments should be given careful consideration. It may be possible to reinforce a sense of social responsibility, and obligation, by CMA officers visiting the sites more frequently, and informing landholders of what other farmers like them are doing (Moore et al. 2018).

The agricultural sector is one of the single greatest contributors to the degradation of river systems worldwide (Belsky et al. 1999; Suding 2011). Projects to exclude stock from grazing riverbanks are amongst the most common river restoration projects. The next challenge is to ensure that these projects, and rive restoration projects more generally, are assessed and maintained to the degree that is required to improve the ecological condition of river systems. Addressing this challenge will involve the following: enhancing the capacity of water authorities to conduct effective monitoring and assessment, supporting landholders to meet challenges associated with climate change, and determining where in the chain of administration the link between state-level guidelines and local and regional practices has broken.

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DATA ACCESSIBILITY

Data used in this study can be provided on request. However, readers should be aware that in compliance with the ethics approval for the research, no data that may identify the landholders or regional authorities involved in the research may be made public.

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Figure captions:

Figure 1. Principles of adaptive management for establishing river restoration projects (adapted from Rutherfurd et al (2001)).

Figure 2. Frequency of common farming activities (sheep, cattle and mixed farming, whereby mixed farming refers to a combination of cropping, lifestyle, and stock) in CMA A, CMA B, CMA C.

Figure 3. Long-term and two-year (2013-2014) annual average rainfall for CMA A, CMA B, and CMA C.

Table 1. Hypotheses and statistical data analysis methods

1	No relationship between stock exclusion and fence condition.	Chi Square
2	Sites in CMA A with continued grazing will contain less cover of juvenile trees than sites with stock exclusion.	t-test
3	Sites in CMA A with continued grazing will contain less than 5% coverage of juvenile trees, while sites with stock exclusion will contain 5% or greater coverage of juvenile trees.	
4	Sites in CMA A with continued grazing will contain less native vegetation than sites with stock exclusion.	
5	No difference for abundance of invasive vegetation between sites in CMA A with continued grazing and sites with stock exclusion.	
6	Sites in CMA C with continued grazing will contain less juvenile tree coverage, than sites with stock exclusion.	
7	No difference for abundance of invasive vegetation between sites in CMA C with continued grazing and sites with stock exclusion.	

Table 2.

CMA	Assessment method	Vegetation Measures
A	Consistent with EVC guidelines	Continuous scale % cover 0-100
B	Method devised by CMA.	Poor, medium, good
C	State-sanctioned Rapid assessment method	Categorical scale 1-5

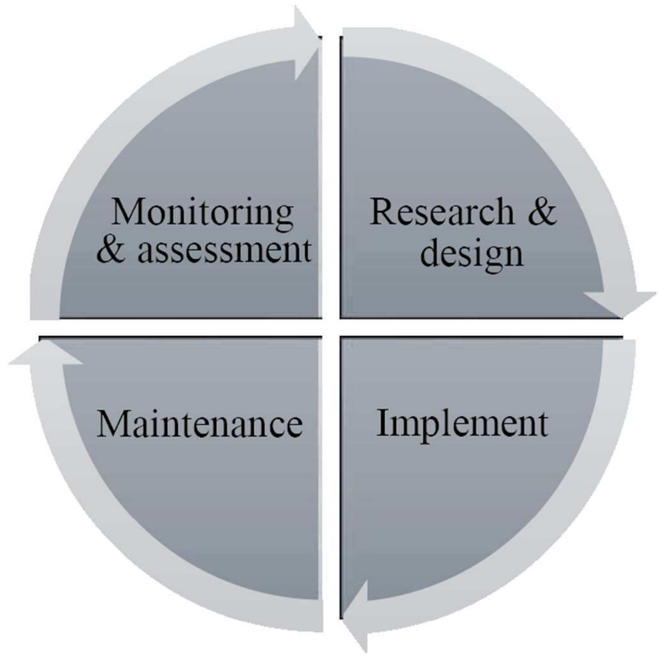
Table 3. Summary of grazing practices

CMA	Grazed	Excluded	No stock/insufficient data
A	65	71	1
B	13	25	12
C	16	27	1
Total	94	109	14

Table 4. Descriptive statistics for measures of vegetation condition in CMA A and CMA C

	N	Mean	SD
CMA A Juvenile tree cover (%)	133	3.29	7.79
CMA A Total native vegetation cover (%)	133	22.56	22.54
CMA A Total invasive species cover (%)	127	27.66	18.77
CMA C Abundance of juvenile trees*	44	2.66	.78
CMA C Abundance of invasive species*	44	3.27	1.13

*Juvenile tree cover for CMA C was measured on a scale of 1 to 5 where the value of 1 represents the least amount of cover and the value of 5 represents the most amount of cover.
*Abundance of invasive species cover was measured on a scale of 1 to 5 where the value of 1 represents the least amount of cover and the value of 5 represents the most amount of cover.



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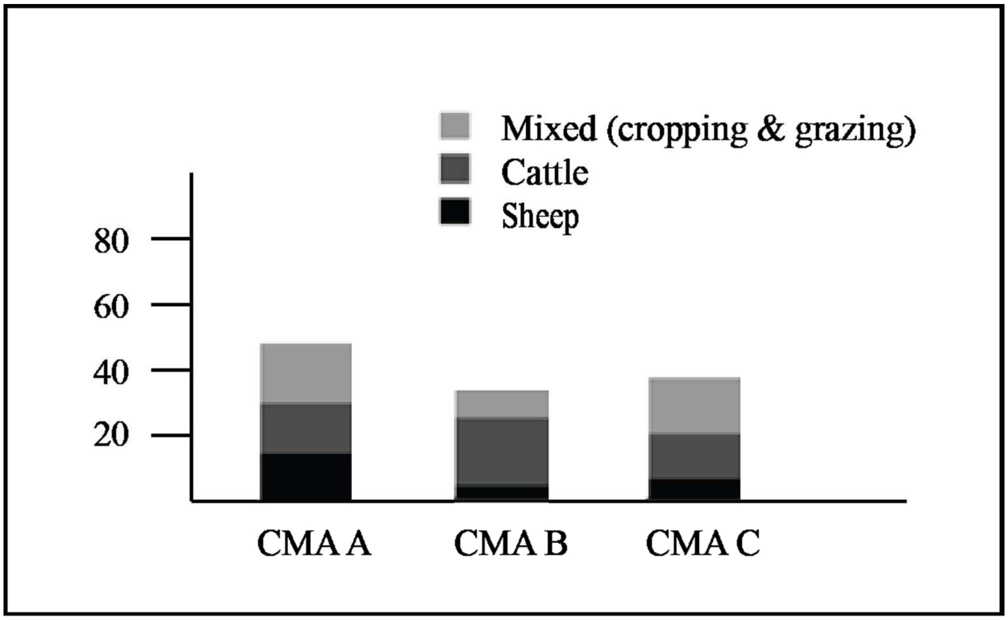

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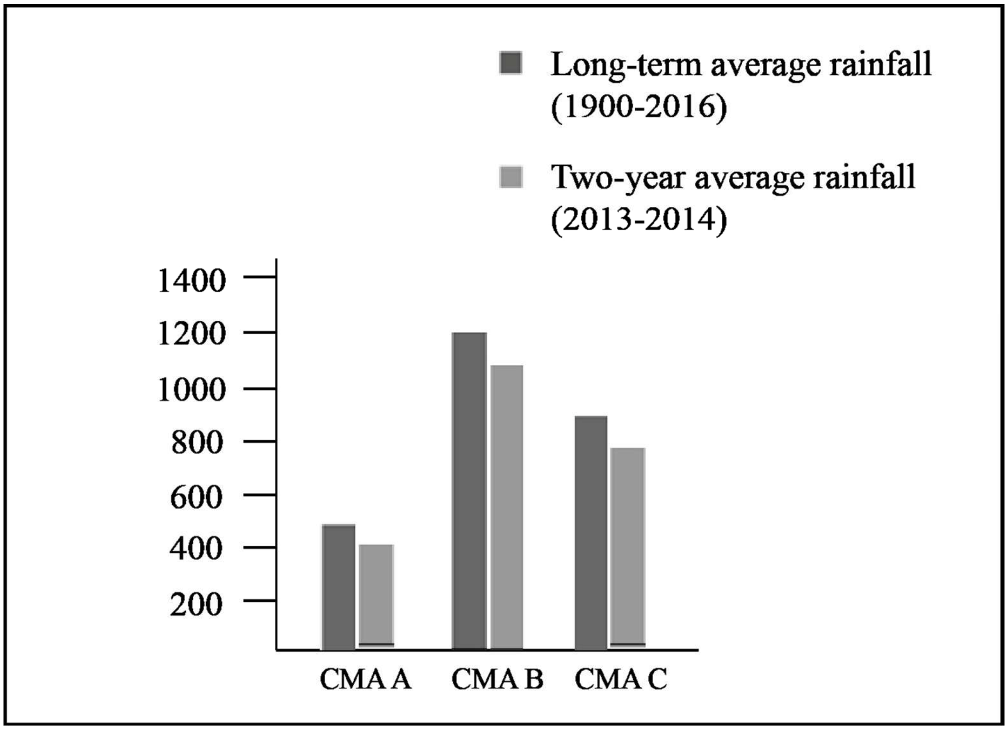

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