Habitat Management and Conservation of the Critically Endangered Plains-wanderer on the Northern Plains of Victoria:

FROM PATCH TO LANDSCAPE SCALE

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RESEARCH CENTRE FOR FUTURE LANDSCAPES

Contents

Slender Darling-pea, Swainsona murrayana,
on the Northern Plains Grasslands of Victoria, listed as Endangered under the FFG Act 1988 and Vulnerable under the EPBC Act 1999.

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Project background: STUDYING THE PLAINS-WANDERER AND THE NORTHERN PLAINS GRASSLANDS

01

The Plains-wanderer is a small, largely terrestrial bird that occurs in lowland native grasslands across eastern Australia. Although quail-like in appearance, Plains-wanderers are related to shorebirds and are the sole member of the family Pedionomidae – an ancient Gondwanan lineage of Australian birds (Olson and Steadman 1981; Figure 1). Habitat loss and degradation are key threats to the Plains-wanderer and have led to a major range contraction and population decline over the last 100 years (D'Ombrain 1926). Today, the species is listed as Critically Endangered under federal legislation and Endangered under the IUCN Red List (Commonwealth of Australia 2016; IUCN 2022). As a species at high risk of extinction and the sole representative of millions of years of evolution, the Plains-wanderer is considered to be of outstanding global conservation importance (Jetz et al. 2014) and regarded by some as the bird species of highest priority for conservation action globally (EDGE 2022).

The Plains-wanderer is one of the most cryptic birds in Australia. Until now, almost all ecological knowledge of Plains-wanderers has come from the detection of nocturnally roosting individuals and habitat assessments at fine-scales that indicate open swards are preferred habitat (Figure 2). This has presented a barrier to identifying other important habitat attributes, whether these change at different spatial scales and how to best manage habitat.

Figure 1. *Female Plains-wanderers (pictured) are larger and more colourfully plumaged compared to males. Females defend a territory and attract mates with far-reaching, deep 'oom' vocalisations. Photo credit, Julian Teh.*

The lowland tussock-forming grasslands of south-eastern Australia, home to the Plains-wanderer, are among Australia's most threatened and poorly conserved ecosystems (Kirkpatrick et al. 1995). The Northern Plains Grasslands of Victoria form part of the Critically Endangered *Natural Grasslands of the Murray Valley Plains* and provide important habitat for the Plains-wanderer (TSSC 2012; Figure 3). They are highly degraded, occurring in a landscape dominated by cropping, beef and dairy production with multiple, fragmented conservation areas enmeshed within the agricultural matrix. The distinct vegetation types of Northern Plains Grassland are influenced by a mosaic of poorly-drained red and grey clays that typically vary spatially at scales of tens of metres. Most grasslands have a long-history of livestock grazing, as well as episodic cultivation. In addition, many exist in a degraded state that lacks floristic diversity and are dominated by grazing-tolerant C3 grasses including Wallaby Grasses (*Rytidosperma* spp.), Spear Grasses (*Austrostipa* spp.) and Spider Grass (*Enteropogon acicularis*). At high-quality grasslands, least disturbed by historical land use, perennial native herbs such as daisies (*Chrysocephalum apiculatum*, *Calocephalus citreus*), saltbush (*Maireana* spp., *Scleroleana* spp.), lilies (*Arthropodium* spp., *Bulbine bulbosa*, *Microseris walteri*) and Swainson-peas (*Swainsona* spp.), as well as biological soil crusts, occupy inter-tussock space.

The grasslands of the Northern Plains provide important habitat for a range of unique plants and animals. In addition to the Plains-wanderer, there are many other threatened species, ranging from reptiles to invertebrates to plants (Table 1). Grassland birds are the most visible vertebrate faunal community and act as useful indicator species of grassland condition (DSE 2010). The grassland bird community is relatively low in richness (~nine species) compared to other grassland biomes (e.g. prairies of North America, >20 species) but nonetheless comprises species with preferences for a variety of different vegetation structures (Antos and Williams 2015).

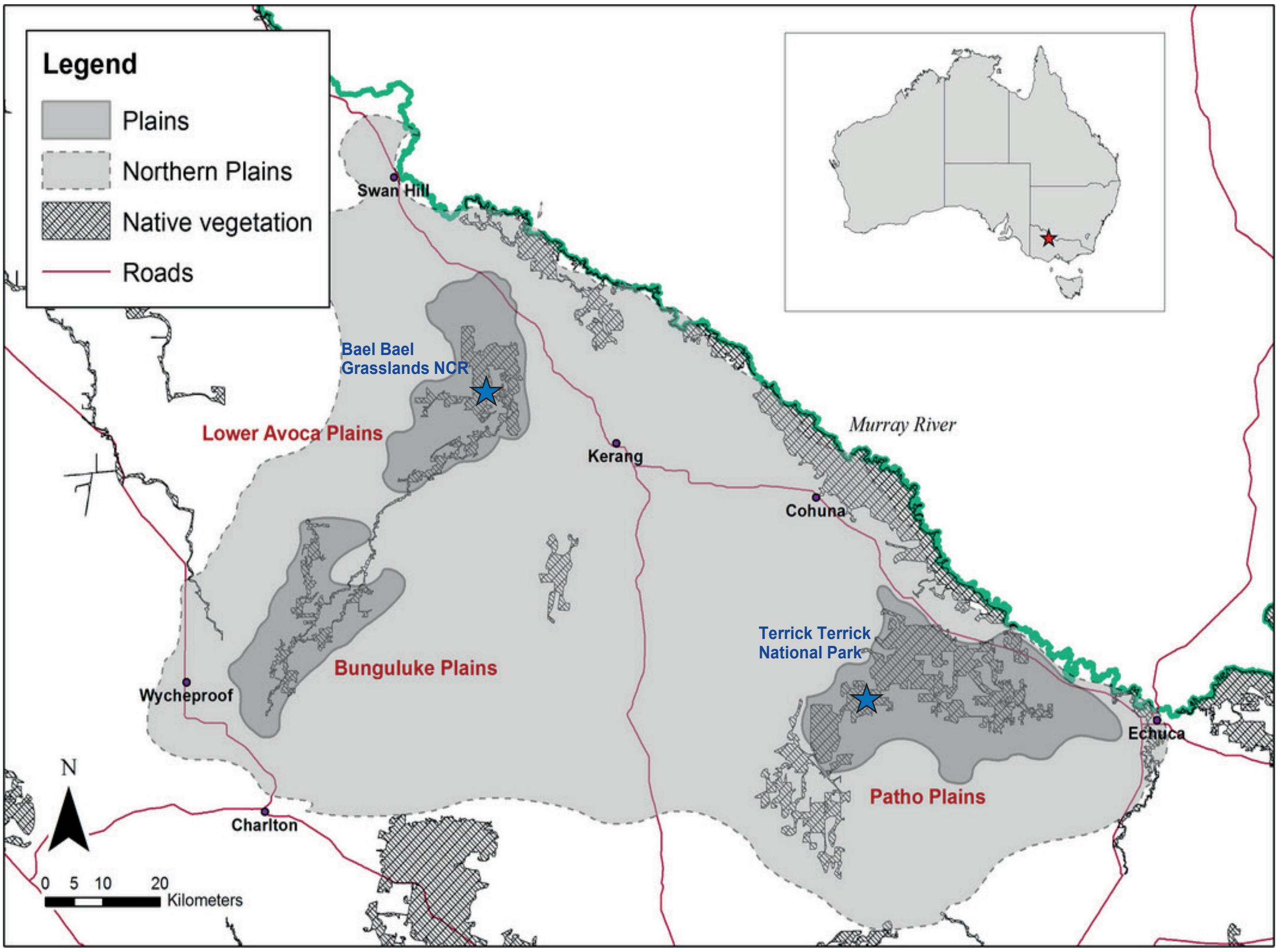
Australian grasslands are a highly dynamic environment. Climate patterns, characterised by flooding rains and intense drought, as well as annual seasonal cycles drive frequent and rapid changes in grassland structure and food resources for fauna. Adding to this dynamic, most Plains-wanderer habitat exists in a patchwork of different land use (conservation versus production) and farm types (sheep versus cattle production) that affects how grasslands are managed. Disturbance is key to habitat management for grassland fauna, but not all disturbance types are necessarily interchangeable. Different types of disturbance can have positive, neutral or negative impacts on specific species and habitat attributes, particularly where land-use legacies have shifted a community to a novel ecological state.

From 2017 to 2021, research has been conducted across the Northern Plains Grasslands of Victoria to examine habitat requirements of the Plains-wanderer and how different disturbance types influence habitat suitability for the species across space and time. The project aimed to produce empirical evidence that can be used by land managers and conservationists to improve habitat management for the Plains-wanderer and other grassland biota. The study addressed four main questions:

1. What habitat attributes are Plains-wanderers selecting for during the day?
2. How do differences in management goals between conservation areas and livestock production land influence Plains-wanderers and their habitat across space and time?
3. Is it better to manage habitat for Plains-wanderers using sheep or cattle grazing?
4. Can a switch in the type of disturbance improve habitat suitability for Plains-wanderers and other grassland birds?

This booklet summarises the main findings from Dan Nugent's PhD project and outlines key implications stemming from this work for grassland management and conservation efforts aimed at improving the conservation trajectory of the globally significant Plains-wanderer on the Northern Plains of Victoria.

Figure 2. PhD candidate, Dan Nugent and co-supervisor, David Baker-Gabb, processing a wild Plains-wanderer for GPS-tracking. Night is the best time to survey and catch Plains-wanderers as they do not elicit the same active human/predator avoidance strategies that make them near-impossible to observe during the day. Photo credit: Rohan Clarke.



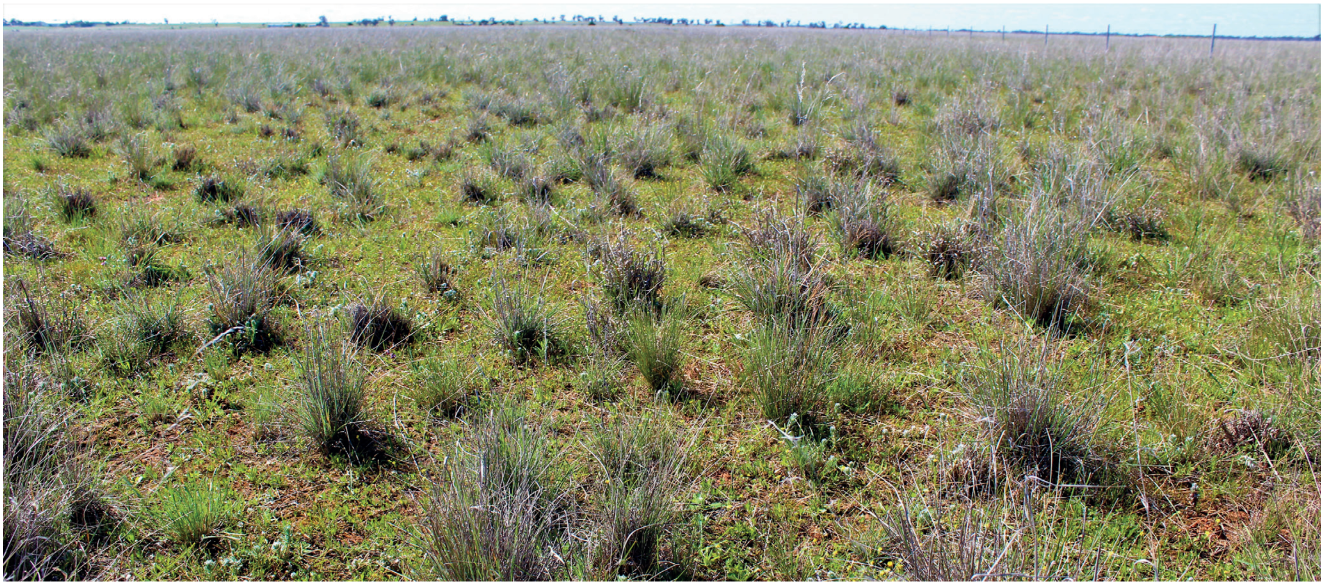


Figure 3.1. Study region: top, distribution of native grasslands across the Northern Plains of Victoria (image courtesy Baker-Gabb et al. 2016); bottom, tussock-gap structure typical of Northern Plains Grasslands;

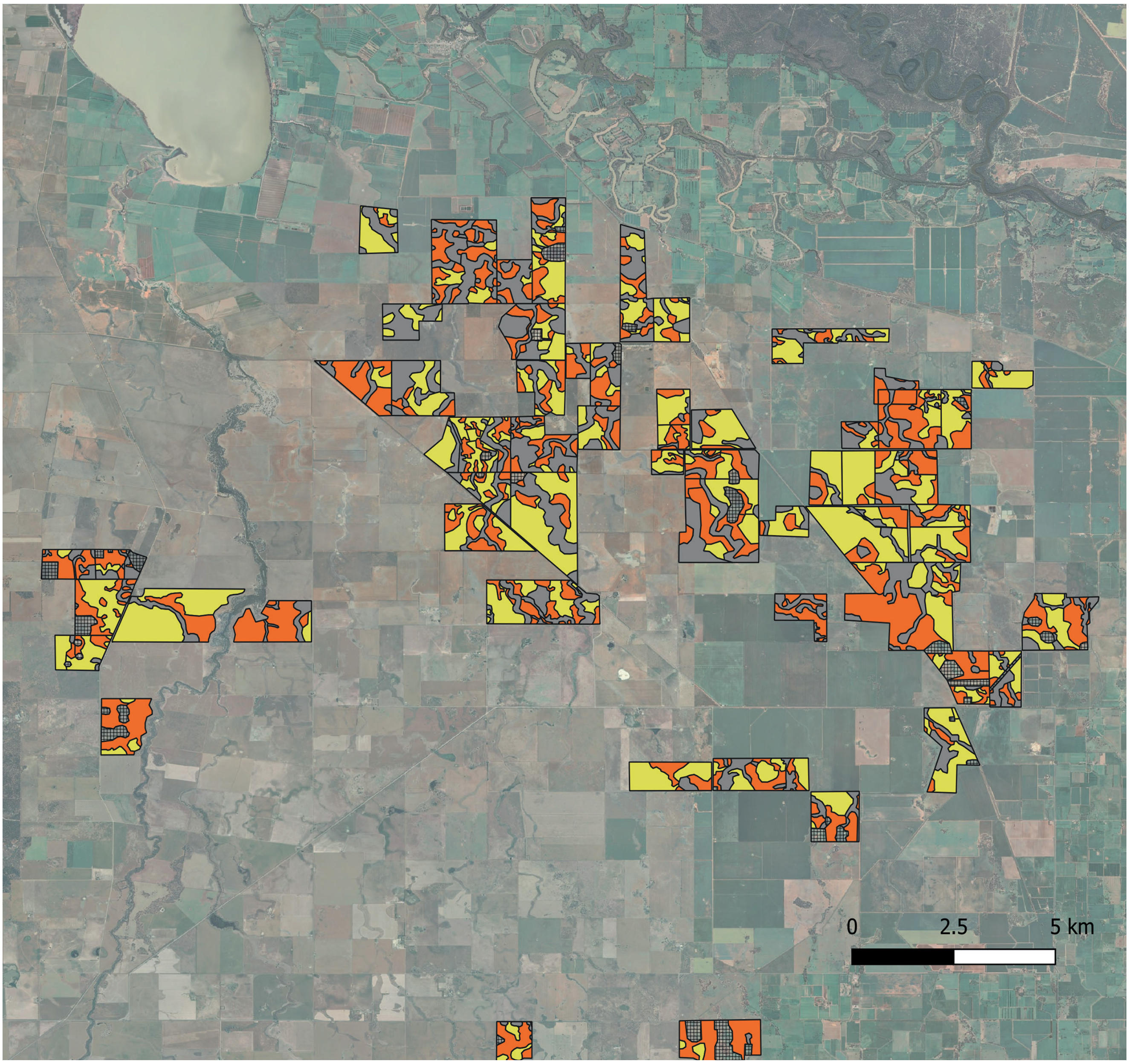


Figure 3.2. Study region: bottom, distribution of soil-derived grassland types (orange indicates red soil grassland, mustard indicates mosaic soil grassland, grey indicates grey soil grassland) across the Patho Plains of Victoria.

Table 1. Key threatened plants and animals of the Northern Plains Grasslands of Victoria (FFG 2022).

Taxa Group	Species	FFG Advisory List	EPBC List
Mammals	Fat-tailed Dunnart *Sminthopsis crassicaudata crassicaudata*	Vulnerable	
Birds	Plains-wanderer *Pedionomus torquatus*	Critically Endangered	Critically Endangered
	Black Falcon *Falco subniger*	Critically Endangered	
	Inland Dotterel *Peltohyas australis*	Vulnerable	
	Red-chested Button-quail *Turnix pyrrhothorax*	Endangered	
Reptiles	Bearded Dragon *Pogona barbata*	Vulnerable	
	Hooded Scaly-foot *Pygopus schraderi*	Critically Endangered	
Invertebrates	Golden Sun Moth *Synemon plana*	Vulnerable	Vulnerable
	Pale Sun Moth *Synemon selene*	Endangered	
Plants	Chariot Wheels *Maireana cheelii*	Endangered	Vulnerable
	Red Swainson-pea *Swainsona plagiotropis*	Endangered	Vulnerable
	Slender Swainson-pea *Swainsona murrayana*	Endangered	Vulnerable
	Silky Swainsona-pea *Swainsona sericea*	Endangered	
	Spiny rice flower *Pimelea spinescens subsp spinescens*	Critically Endangered	Critically Endangered
	Turnip copper-burr *Sclerolaena napiformis*	Critically Endangered	Endangered

New Insights Into The
Behaviour And Habitat Requirements Of The Plains-wanderer

02

Our understanding of habitat needs of grassland fauna is often incomplete because of their cryptic behaviour. This is particularly true for the Plains-wanderer. Over several decades, findings from vegetation assessments at locations where Plains-wanderers roost have informed an understanding of what constitutes preferred roosting habitat – typically, sparse vegetation on red soils (Baker-Gabb 1988, Baker-Gabb 2016, Baker-Gabb et al. 2016, DPIE 2020). Because of the extreme wariness and excellent camouflage of Plains-wanderers during the day it has been difficult to determine if the birds' preference the same type of vegetation as at night or use the spectrum of different vegetation structures available to them across a site.

Our project identified what habitat attributes Plains-wanderers are selecting for and against at multiple spatial scales using different tools for detection of individuals and tracking movements (bioacoustics recorders, GPS tracking, spotlighting) and habitat assessments (remote sensing, on-ground survey). We found birds are not selecting home ranges with a unique composition or configuration of soil-derived grassland types relative to what is available within the landscape. In other words, a Plains-wanderer could disperse to any random part of the grassland landscape and find a suitable mix of grassland types to meet their needs.

Results suggest habitat attributes at the site, patch and fine-scale are most important to habitat selection by Plains-wanderers (Table 2). Based on 11 years of nocturnal population monitoring data, we found Plains-wanderers were more likely to occur at sites with an increasing proportion of vegetation openness in a range between 13.5 and 16 golf-balls (Nugent et al. 2022b). Using bioacoustic recorders as a detection tool, Plains-wanderer presence was found to be positively associated with denser vegetation in the drought years of 2018-2020 (Nugent et al. 2022c). Habitat characteristics of home-ranges were identified using miniature GPS trackers fitted to adult Plains-wanderers and detailed on-ground assessments (Nugent et al. 2022a; Figure 5). Home-ranges averaged 32 ha (SD 26 ha) and were characterised by a high proportion of red and/or mosaic soils, with a smaller amount of grey soil. We found Plains-wanderers selected for vegetation with higher grass and lichen cover, whilst avoiding areas where structure was impacted by high exotic plant cover.

At the fine-scale, we found daytime foraging occurred in denser swards than those of nocturnal roosting sites suggesting that Plains-wanderers require grasslands with both open and denser swards to support different behaviours (Figure 6). Considering these new ecological insights, it is important that the existing guidelines for the classification of habitat suitability based on vegetation structure be revised to assist land managers. Where previously sparse vegetation on red soil (14-16 golf balls) had been categorised 'ideal habitat', a combination of sparse (15-17 golf balls for roosting and foraging) and slightly denser vegetation (12-14 golf balls for foraging and nesting) likely better represents preferred or 'ideal' habitat (Figure 7). Success in achieving structural diversity goals could be measured by quantifying variation or spread of golf ball scores recorded from across a site at different points in time.

Implications For Practice

- Biomass management should aim to promote structural heterogeneity (Figure 8), with areas of open (14-17 golf balls) and slightly closed vegetation (11-13.5 golf balls) at the home-range scale (30 ha)
- Control of exotic plant invasions such as Erodium spp. should be a priority for management
- All grassland should be regarded as potential Plains-wanderer habitat (not just red soil vegetation types) and considered for protection (i.e. strategic stock fencing) and active biomass management
- Practices that damage soil crusts should be avoided

Table 2. Habitat attributes that Plains-wanderers were found to show preference towards at different spatial scales.

Spatial scale	Plains-wanderers selected for
Landscape (>100 ha)	High proportion of red and/or mosaic soil vegetation (Nugent et al. 2022b)
Site/reserve (10-100 ha)	High proportion of vegetation structure ranging 13.5 to 16 golf-balls (Nugent et al. 2022b) Denser vegetation in dry years (Nugent et al. 2022c)
Home-range/patch (1-50 ha)	High native grass cover (Nugent et al. 2022a) High lichen cover (Nugent et al. 2022a) Lower cover of exotic herbs (Nugent et al. 2022a)
Fine-scale (<1 ha)	Denser swards for daytime foraging (Nugent et al. 2022a) Open swards for nocturnal roosting (Nugent et al. 2022a)

Study approach: GPS-tracking to understand the movements and habitat use of Plains-wanderers

Using miniature GPS-VHF combined tags (<2 g), we tracked the movements of 13 adult Plains-wanderers over five to eight days on the Northern Plains of Victoria (Figure 4). On-ground and desktop-based habitat assessments were used to investigate what habitat attributes Plains-wanderers are selecting for and against at varying spatial scales. At the fine scale (<1 ha), we compared habitat attributes between roost (night) and foraging (daytime) sites. At the patch-scale (1-50 ha), we compared habitat attributes between patches of grassland used (i.e. an individual's home range) and that not used during the tracking period. At the landscape-scale (>100 ha), we used a map of grassland types associated with distinct soil types (red soil, mosaic soil and grey soil) to test if Plains-wanderers display non-random 'choice' in where they establish a home-range.

Figure 4. VHF radio-tracking was used to re-locate Plains-wanderers fitted with trackers after eight days. GPS tags used for the study were too small to support a remote download feature, so VHF tags were combined with GPS tags to make a single unit.
Photo credit; Thomas Dell'Oro

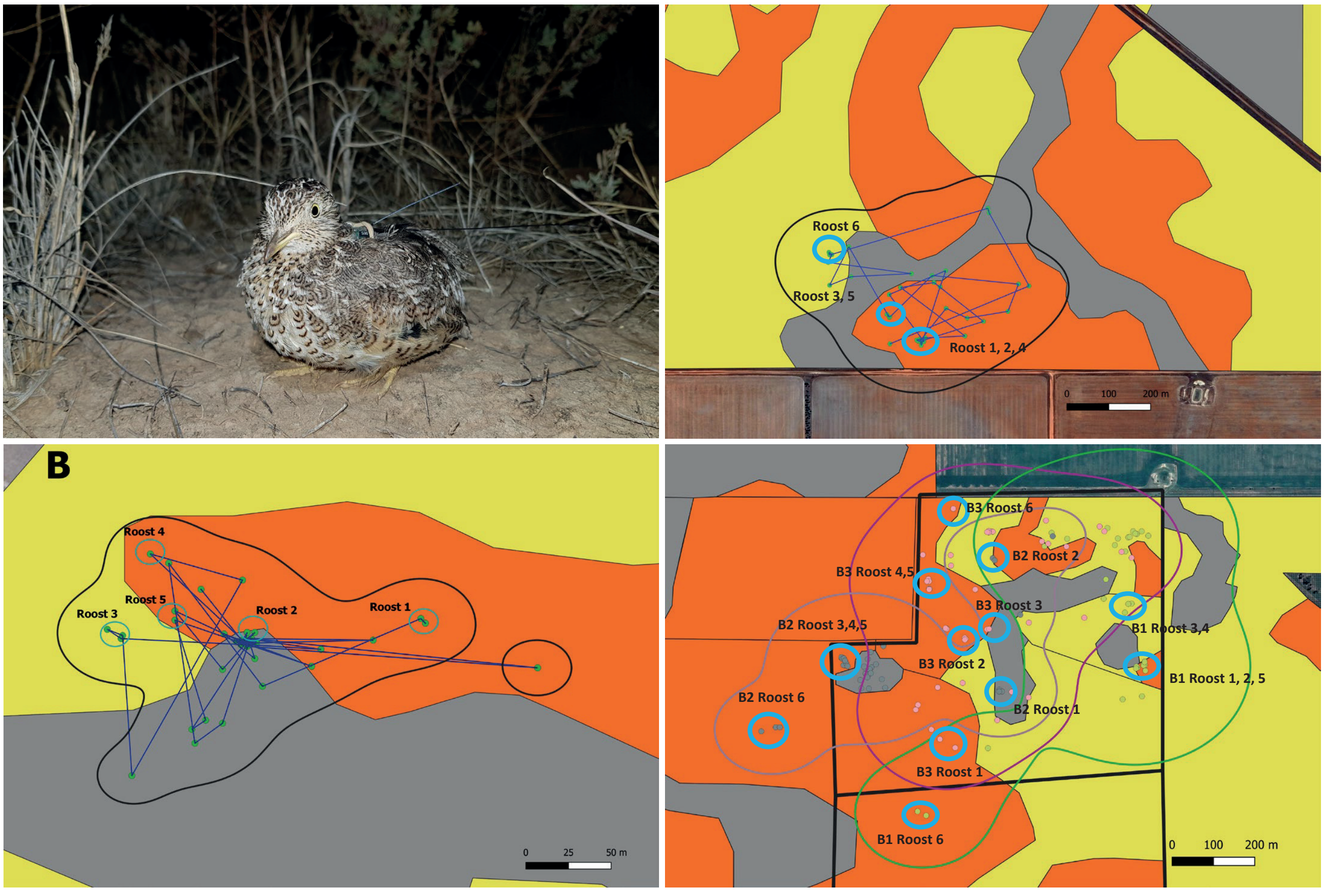


Figure 5. Top-left, an adult male Plains-wanderer with an elastic band backpack harness carrying a <2 g VHF-GPS combined tracker. Top-right, home range of a Plains-wanderer that showed random selection of grassland types. Bottom-left, home-range of male Plains-wanderer that showed non-random selection of grassland types. This individual was considered to be nesting in denser vegetation as it displayed strong fidelity to a central point and made frequent return trips. Bottom-right, highly overlapped home ranges of three Plains-wanderers (labelled B1, B2 and B3) that highlights roosting (blue circles) most frequently occurs in sparse, red soil vegetation.

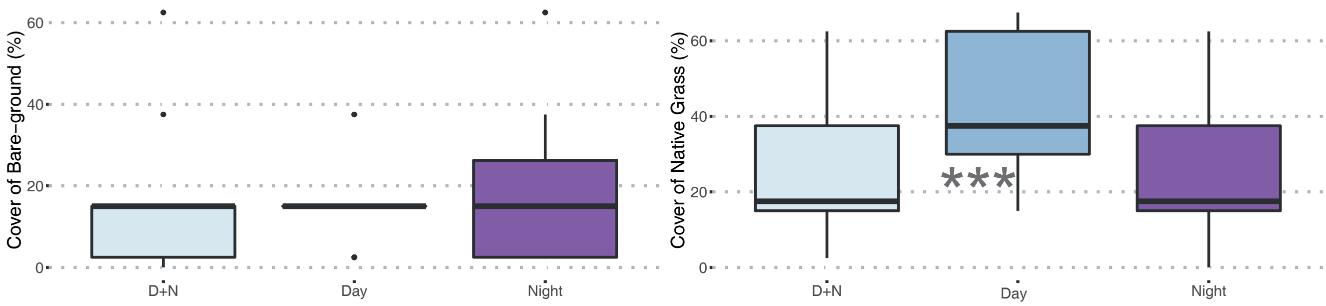


Figure 6. Comparison of (i) vegetation openness (measured by golf ball score) and (ii) cover of native grass used for roosting (purple), foraging (dark blue) and both foraging and roosting (‘both’, light blue) by Plains-wanderers (n = 11). We found moderate and strong evidence, respectively, that Plains-wanderers selected for denser vegetation and higher cover of native grass for daytime foraging compared to roosting habitat.

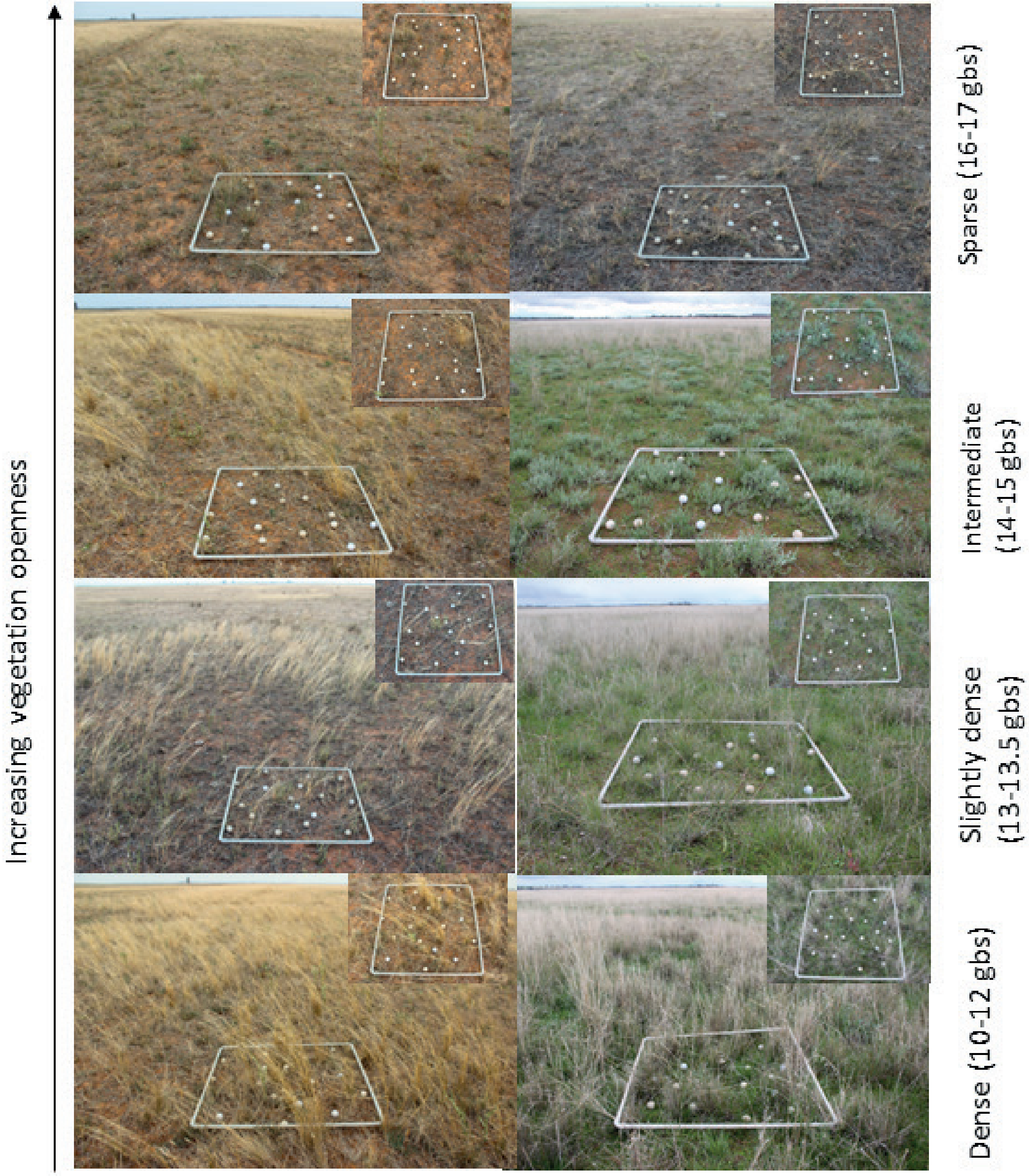


Figure 7. Structural heterogeneity, detailed in golf balls scores (gbs), is important to meet the different behavioural needs of the Plains-wanderer. Sparse and intermediate vegetation structure is important for roost and foraging sites. Slightly dense and, to a lesser extent, dense vegetation provides important foraging and nesting habitat. Management should aim to produce a mix of these different structural types across a site, with the highest proportion of vegetation in an intermediate structural range.

Figure 8. Example of structural heterogeneity at a patch-scale driven by a shift in vegetation composition from a sparse cover of Spider-grass *(Enteropogon acicularis)* to a dense sward of Spear-grass *(Austrostipa scabra* (circled)). Such structural diversity should be viewed as an indicator of good biomass management and the absence of overgrazing.

Research For The Future

Our findings provide evidence that vegetation structure influences where Plains-wanderers forage. The type and abundance of seeds and invertebrates can be strongly associated with grassland structure, so a key question remains: what role does food availability play in habitat selection by Plains-wanderers? Are Plains-wanderers responding to the safety and shelter afforded by denser vegetation or a specific food resource or both?

We found Plains-wanderers show preference to open vegetation at nocturnal roosts. Why they would choose this habitat type is unclear, but we speculate it may relate to their crepuscular calling and courtship behaviour. Stemming from this, an important question is do Plains-wanderers use open, short vegetation as display arenas during loose congregations of breeding adults (i.e. similar to leks undertaken by Sage-grouse in prairies)?

Understanding what factors influence breeding success is critical to managing habitat for threatened species. The short duration of tracking periods associated with the type of wildlife trackers available for our study meant it was not possible to assess the effect of different habitat attributes on breeding outcomes. Future studies should seek to answer: what is the optimal configuration of different vegetation structures at a home-range scale for breeding success?

Plains-wanderers occur in a diverse range of habitats across eastern Australia – from chenopod-dominated plains in South Australia to Mitchell grass sub-tropical grasslands in Queensland. Historically, temperate grasslands of southern Victoria were also important habitat. Our study focused on habitat selection by Plains-wanderer in the semi-arid grasslands of northern Victoria. Therefore, we are limited in our ability to infer habitat use in other ecosystems. We suggest future studies investigate if habitat requirements for Plains-wanderers differ between the Northern Plains of Victoria and other regions.

Figure 9. Plains-wanderer roosting together at night. Photo credit, Julian Teh.

GRAZING MANAGEMENT OF PLAINS-WANDERER HABITAT 03

Habitat for fauna in grasslands is highly dynamic, shaped by biotic and abiotic processes. Major changes in vegetation structure and food resources can occur frequently and over short periods of time. This dynamism makes it difficult for land managers to maintain habitat structure in a state preferred by the Plains-wanderer. Historically, semi-arid and temperate grasslands supported a more even mix of perennial herbs such as lilies, everlasting daisies and perennial tussock grasses (Foreman 1996). Today, perennial grasses are dominant, with many native herbs rare or uncommon in most grasslands. Annual grasses, which have a major influence on biomass fluctuations, were absent in pre-European grasslands. In this historical state, it is postulated that frequent (annual) disturbance would not have been critical to maintaining an optimal vegetation structure for the Plains-wanderer, particularly in low productivity, semi-arid grasslands.
Following decades of degradation from overgrazing by livestock, cultivation and invasion by weeds, today most grasslands exist in grass-dominated states that are dependent on frequent disturbance to maintain an open structure (Figure 9). The importance of livestock grazing to management of vegetation structure for the Plains-wanderer has been widely described over the past three decades (Baker-Gabb et al. 1990, 2016, Maher and Baker-Gabb 1993). However, several key knowledge gaps have surrounded the effects of livestock grazing on the Plains-wanderer and its habitat. First, Plains-wanderers occur across livestock production farms and conservation reserves, but it has been unclear how different grazing approaches related to land use type (conservation, livestock production) affect habitat suitability for the Plains-wanderer. Second, sheep and cattle are both used to manipulate vegetation structure in conservation reserves, but how these different grazer species impact habitat has remained unstudied and it has been unclear if they are similarly effective as a management tool.

Livestock Production Farms And Conservation Areas Play A Complementary Role In Plains-wanderer Conservation

Our study found that land used for livestock production can complement conservation areas by providing preferred habitat for the Plains-wanderer during years of high rainfall when grass growth is promoted (Nugent et al. 2022b). Habitat suitability for the Plains-wanderer (measured by the proportion of modelled golf ball scores between 13.5 and 16 at a site) was driven by an interaction between land-use type and rainfall, with conservation areas supporting more areas of preferred habitat structure during dry periods, but less during wet periods (Figure 11). By contrast, Plains-wanderers were more likely to occur on livestock production farms during wet periods. We speculate this is because higher grazing pressure on livestock production farms was able to limit biomass accumulation and maintain more areas of preferred habitat structure. There are distinct advantages and disadvantages associated with conservation areas and livestock production farms that must be recognised in conservation planning for the Plains-wanderer (Table 3).

Our findings suggest strategic, landscape-scale planning and effective agri-environmental initiatives will be critical to the future of the Plains-wanderer. Overgrazing on private land during drought that causes vegetation structure to become too sparse for the Plains-wanderer is likely a symptom of financial stress (farmers cannot afford to completely destock and then restock when conditions become more productive) and/or farming approach/culture (farmers do not perceive overgrazed vegetation as an issue for biodiversity, ecosystem function or animal productivity). To reduce the likelihood of overgrazing in dry periods, a combination of effective financial levers and education are needed. At present, conservation covenants are the most effective tool for the long-term protection of habitat from overgrazing and conversion to cropping on the Northern Plains of Victoria. The limitation of this strategy is that interest in the program generally exceeds the money available to compensate landholders for restricting their land use options. Other market-based strategies founded in a strong ecological understanding of grasslands should be investigated as a way of complementing the conservation covenanting program. Biodiversity-friendly certification schemes that inform consumers of the positive outcomes of particular farming practices and potentially facilitate products to be sold at a premium, could be a suitable alternative which requires investigation. An additional advantage of such schemes is that they are not tied to government funding cycles.

Our results highlight the important role conservation areas can play in preventing temporary habitat loss driven by overgrazing. During times of low rainfall and associated vegetation dormancy, it is important to reduce or completely remove grazing pressure to ensure plant/tussock-gap structure is maintained (Figure 12). This is easier to achieve on public reserves as opposed to farming systems because managers of public reserves are not constrained by market forces. Expansion of the grassland reserve network through land acquisition could have real and substantial conservation benefits for the Plains-wanderer and other grassland species in Victoria. Decisions to add additional land must recognise that grasslands require 'hands-on' active management. Appropriate resourcing for land management agencies will determine the difference between conservation success and failure.

Figure 10. The Northern Plains of Victoria supports a mix of different land use types with conservation areas enmeshed within livestock production land and crops.

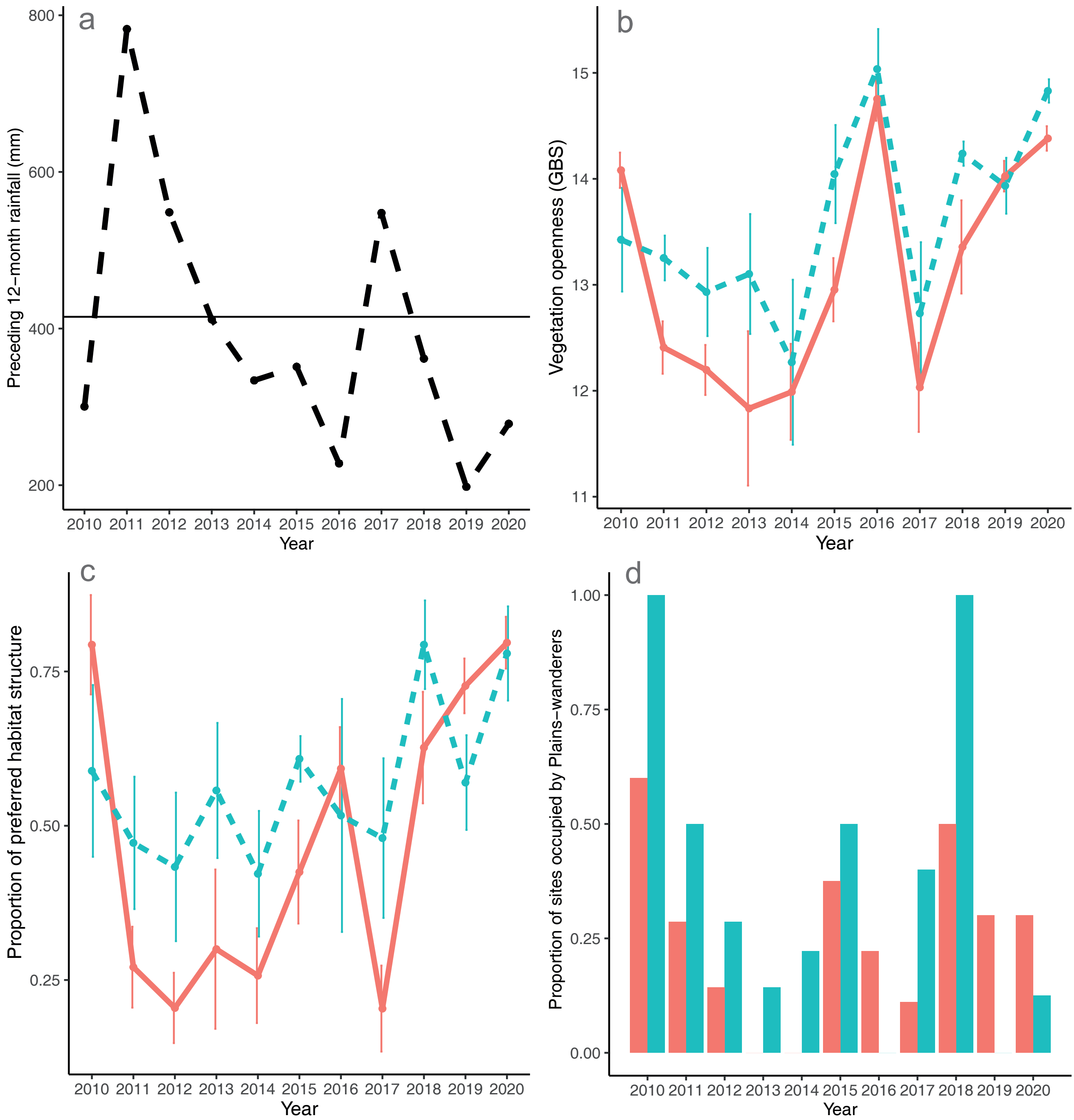


Figure 11. Patterns of rainfall, habitat structure and Plains-wanderer occurrence in grasslands of northern Victoria across the study period, 2010-2020 (blue = livestock production; red = conservation). A) 12-month preceding accumulated rainfall (mm) for each survey year. Surveys were undertaken in autumn and accumulated preceding rainfall is measured from March of the previous year to February of the survey year. Solid horizontal line indicates mean annual rainfall for region (415 mm). B) Modelled vegetation openness (golf ball score) in each land use type (conservation, production) across the study period. C) Proportion of preferred Plains-wanderer habitat (vegetation openness ranging from 13.5 to 16 golf ball score) in each land use type. D) Proportion of sites where Plains-wanderers were detected within each land use type for each year. Bars indicate standard error.

Table 3. Key advantages and challenges of grassland management for conservation in semi-arid areas of south-eastern Australia based on land use. Addressing these 'challenges' should be a priority for policymakers to improve outcomes for grassland management of each land use type.

	Advantages	Challenges
Conservation areas	•Long-term security of conservation tenure (i.e. covenants, national parks) •Governance structure and transparency of management •Access to expertise and land management staff •Not constrained by agri-economic forces •Legislative obligations and public accountability	•Internal processes can hamper rapid responses •Reliance on external parties to provide and remove stock •Competing management interests •Consultative approach can yield a dichotomy of management approaches •Fluctuations in budgets that impact staffing and other resources
Livestock production areas	•High level of stewardship and on-ground presence •Rapid and responsive unilateral decision making •Local knowledge of grassland and grazing impacts •Ready access to stock and expertise	•Lack of long-term tenure security and subject to manager turn over •Subject to economic drivers •Knowledge, skills and attitudes of landholders vary •Subject to land use change (cropping) •Reliant on agri-environmental incentives that can change with government cycles

Study approach: Assessing the impacts of grazing management associated with livestock production farms versus conservation areas on Plains-wanderers

We used 11 years of Plains-wanderer occurrence data collected during autumn nocturnal, vehicle-based spotlighting and habitat structure data collected via satellite to understand how land use type (conservation, production) interacts with annual rainfall to affect habitat suitability for Plains-wanderers. The number and identity of sites changed between years, but Plains-wanderer occurrence data was typically available for an even mix of 10 to 20 sites across livestock production land and conservation areas for a given year. To estimate vegetation openness at the time and location of each Plains-wanderer survey, a model was developed using a golf-ball score training dataset collected using on-ground vegetation assessments, spectral indices derived from satellite imagery and a machine learning process.

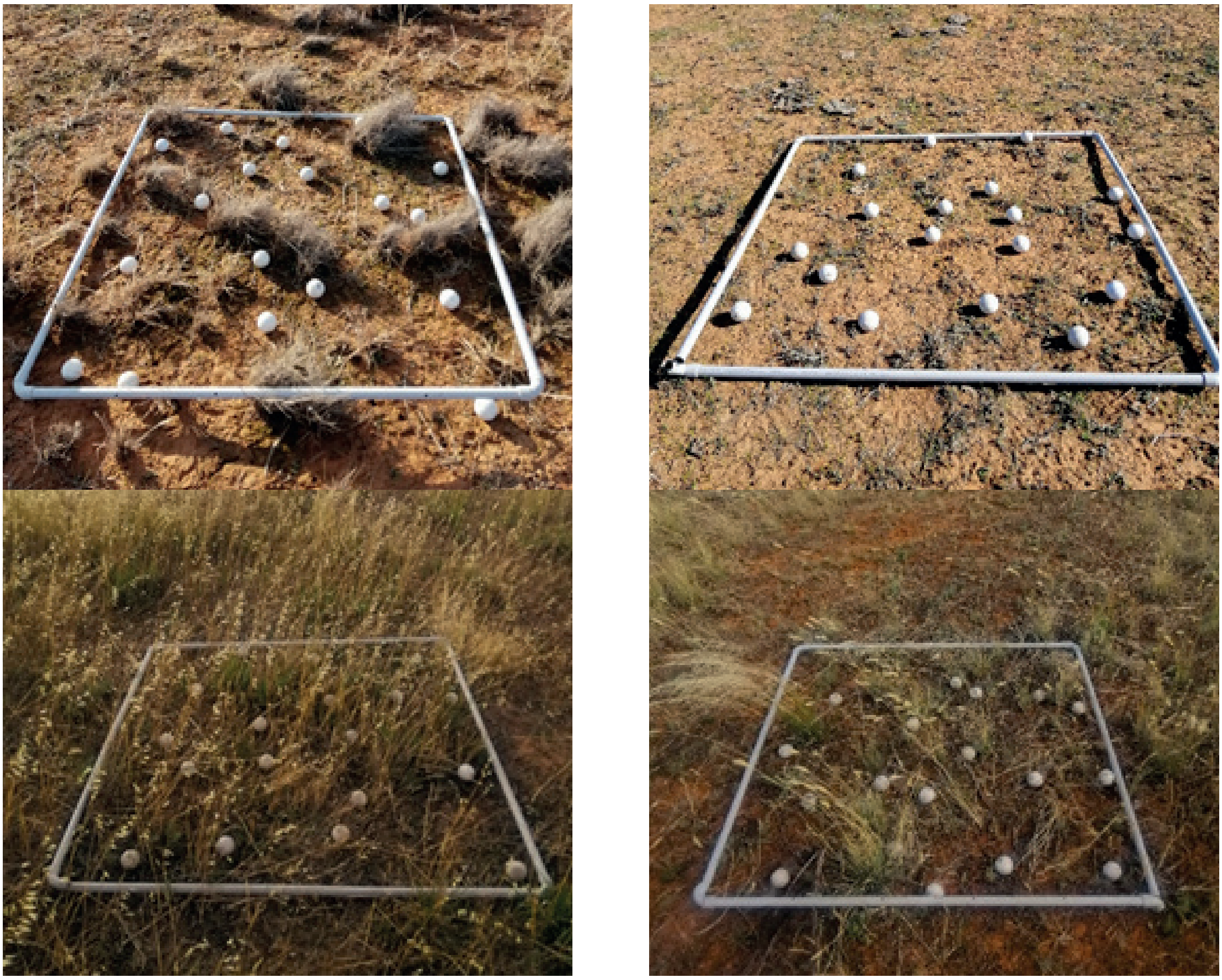


Figure 12. Example of types of vegetation structure driven by an interaction between land use type and rainfall. Note: photographs are not of the same site but show differences characteristic of each land use type during specific rainfall patterns. A) vegetation structure characteristic of destocked grassland in conservation areas and B) overgrazed grassland on production land during drought, 2019. C) vegetation structure characteristic of under-grazed grassland in conservation areas and D) intensively-grazed grassland on production land following a year of high rainfall, 2017.

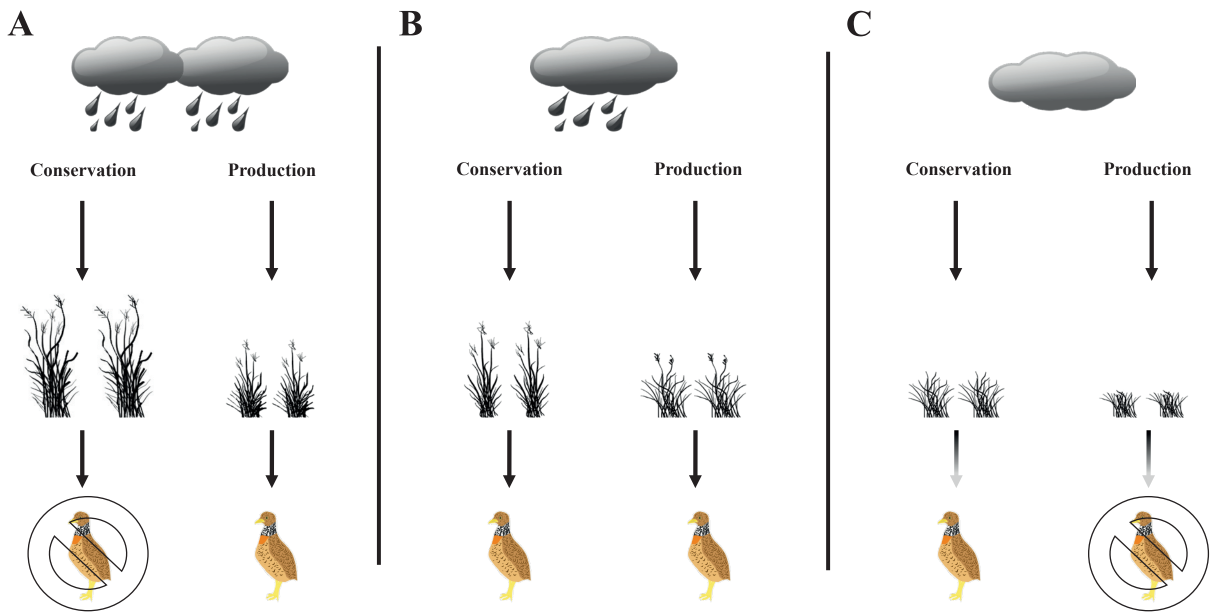


Figure 13. Conceptual model of interactions between climate phase (rainfall) and land use type (conservation, production) affecting vegetation structure and, in turn, Plains-wanderer occurrence in semi-arid grasslands of eastern Australia. A, wet climate phase; an inability to increase livestock grazing pressure in response to increased vegetation growth in conservation areas leads to habitat becoming too dense (i.e. >16 golf-ball score) and therefore unsuitable for Plains-wanderer. In contrast, flexibility of farming practices on production land maintains preferred habitat structure (13.5-16 golf ball score) for the Plains-wanderer. B, 'average' climate phase (rainfall); conservation areas or production land can support preferred habitat structure for the Plains-wanderer. C, dry climate phase (rainfall); areas of preferred habitat structure for the Plains-wanderers are retained in conservation areas as livestock grazing pressure is reduced in response to vegetation dormancy triggered by water-stress. In contrast, vegetation structure becomes too sparse for Plains-wanderers (>16 golf ball score) on production land as livestock grazing continues despite reduced plant growth. Note: Solid black arrows indicate interactions supported by evidence from our study. Incomplete arrows indicate hypothesised interactions.

The Substitutability Of Sheep And Cattle As A Habitat Management Tool For Plains-wanderers Is Dependent On Climatic Conditions

We found different grazers altered the structure of habitat for Plains-wanderers in distinct ways (Nugent et al. 2022c). Grasslands grazed by cattle were typically more open, less variable and lacked patches of dense vegetation relative to those grazed by sheep (Figure 15). We observed no difference in abundance or diversity of food items between grassland grazed by sheep or cattle. Grazer type did not influence the likelihood of Plains-wanderer occurrence, but it did interact with year of survey to affect breeding activity. The number of days with one or more Plains-wanderer calls significantly increased at sheep grazed sites in year-3 which coincided with enduring drought conditions.

As a habitat management tool, sheep or cattle grazing is useful when the goal is to support an open grassland structure for the Plains-wanderer. However, their substitutability is likely dependent upon climate. We caution a loss of dense vegetation in grasslands grazed by cattle during drought could limit the availability of optimal habitat for the Plains-wanderer and habitat for other grassland birds. Cattle may be more effective at maintaining grassland openness for the

Plains-wanderer during wet years when growth of grasses is prolific. This requires further investigation and consideration of other biodiversity values such as soil structure that may be negatively impacted by much heavier cattle whose faeces are deposited in relatively large, discrete lumps and hooves produce deep 'pugs' (Figure 16).

Study approach: Assessing the effects of sheep grazing versus cattle grazing on Plains-wanderers and their habitat

Using a grazing experiment over three years, we determined the effects of grazer type (sheep, cattle) on occurrence and vocal activity of Plains-wanderer, food availability and vegetation structure and composition. We also examined grazer effects on encounter rates of other grassland birds. In total, 30 sites were surveyed across three years, comprising 12 sites in 2018, eight sites in 2019 and 10 sites in 2020. All sites were managed using a 'conservation grazing' approach whereby the goal was to maintain a uniformly open structure (14-16 golf ball score).

A permanent network of over 50 bioacoustics recorders (BARs) was used to monitor the Plains-wanderer population (Figure 14). The female Plains-wanderer has a unique deep 'oooming' call which is used to attract mates and defend a territory. This call can be reliably detected by a BAR within a 150 m radius under calm wind conditions. Spotlight surveys conducted from a 4WD vehicle along fixed transects were used to complement BARs and confirm Plains-wanderers at a site. Vegetation structure was surveyed at ten plots positioned in a grid between 50 to 100 m apart at each site. Invertebrates and seeds were also sampled at these plots.

Figure 14. i), Invertebrates and seeds were sampled using a modified leaf blower. ii), Bioacoustic recorders (BARS; Songmeter SM4) were used to determine the occurrence of Plains-wanderers at site. BARS were programmed to record audio for 1 hour at dusk and dawn. The 'ooming' call of the female Plains-wanderer can be detected from up to 150 m away under calm conditions.

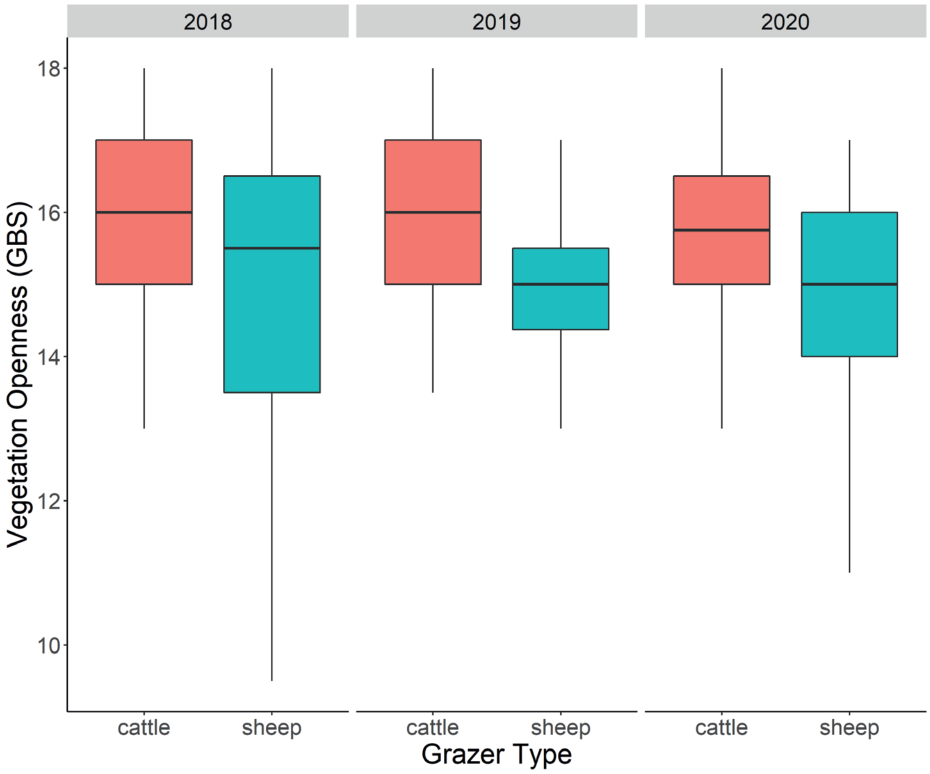


Figure 15. Golf-ball scores recorded at plots in sheep grazed and cattle grazed sites in 2018 (sheep = 60 plots, cattle = 60 plots), 2019 (sheep = 40 plots, cattle = 40 plots) and 2020 (sheep = 50 plots, cattle = 50 plots). Vegetation openness is measured using golf-ball score (GBS). Note: Increasing values equal increasing vegetation openness.

Figure 16. Pugging (left) of soil was strongly associated with grazing by cattle and linked to a decrease in biological soil crusts (right) across the study period. Disturbance of the soil surface also creates an environment that favours exotic grass germination which, in turn, likely leads to a decline in habitat quality for the Plains-wanderer due to loss of inter-tussock space used for foraging.

Implications For Practice

Support sustainable farming initiatives (i.e. conservation covenants, market-based schemes) and practices that limit overgrazing in years of low rainfall (i.e. crash grazing, rotational grazing, destocking in drought)

Implement integrated biomass management strategies in conservation areas to reduce biomass accumulation in years of high rainfall

Sheep grazing should be preferred over cattle grazing as a biomass management tool in years of low rainfall

Research For The Future

Our findings demonstrate that long-term exposure of a grassland to grazing by a single type of grazer can shift vegetation structure to a unique state. Our study did not investigate the short-term effects of a switch between grazer types. Therefore, an important question is what are the impacts of switching (frequently vs infrequently) between cattle and sheep grazing over time?

Rapid biomass accumulation associated with extended periods of high-rainfall is a key challenge of habitat management for the Plains-wanderer. There are also additional challenges associated with public reserves because of the bureaucratic and logistical constraints that impede rapid grazing responses. Additional management tools that are not reliant on livestock would likely enable more effective responses to biomass change. However, there has been no study of other possible techniques such as pyro-herbivory or slashing. Future studies should seek to address this knowledge gap and ask: can pyro-herbivory and slashing assist with reducing high levels of biomass accumulation in/following years of high rainfall?

Halting the cropping and intermittent overgrazing of native grasslands is critical to ensuring complementarity between different land use types and therefore conservation of the Plains-wanderer and its habitat. To address this challenge, a variety of mechanisms are needed to maximise landholder participation in land protection. Future studies should investigate the potential of stewardship and certification schemes to improve grassland management. Specifically, such studies should ask: what is the best market-based mechanism (independent of government funding cycles) that could support sustainable grazing practices and habitat conservation on private land?

Our findings suggest that breeding outcomes of Plains-wanderers on different land use types under different weather patterns may differ. However, the precise mechanisms influencing changes in Plains-wanderer occurrence remain unclear. Future studies should ask: what are the effects of an interaction between land use type and rainfall on breeding success and can this change patterns of occurrence at a farm-scale?

Our study was unable to describe patterns of Plains-wanderer occurrence across different land use types under prolonged, multi-year drought. We speculate that conservation areas may provide refuges from overgrazing for Plains-wanderers at such time. Future studies should seek to test this hypothesis and ask: do conservation areas provide refugia from overgrazing on production land during intense drought?
To persist in a landscape characterised by dynamic changes in habitat suitability and fragmented remnant grassland, Plains-wanderers must be mobile and able to find suitable habitat structure when it becomes available. A key question remains: how does patch size and connectivity influence Plains-wanderer populations?

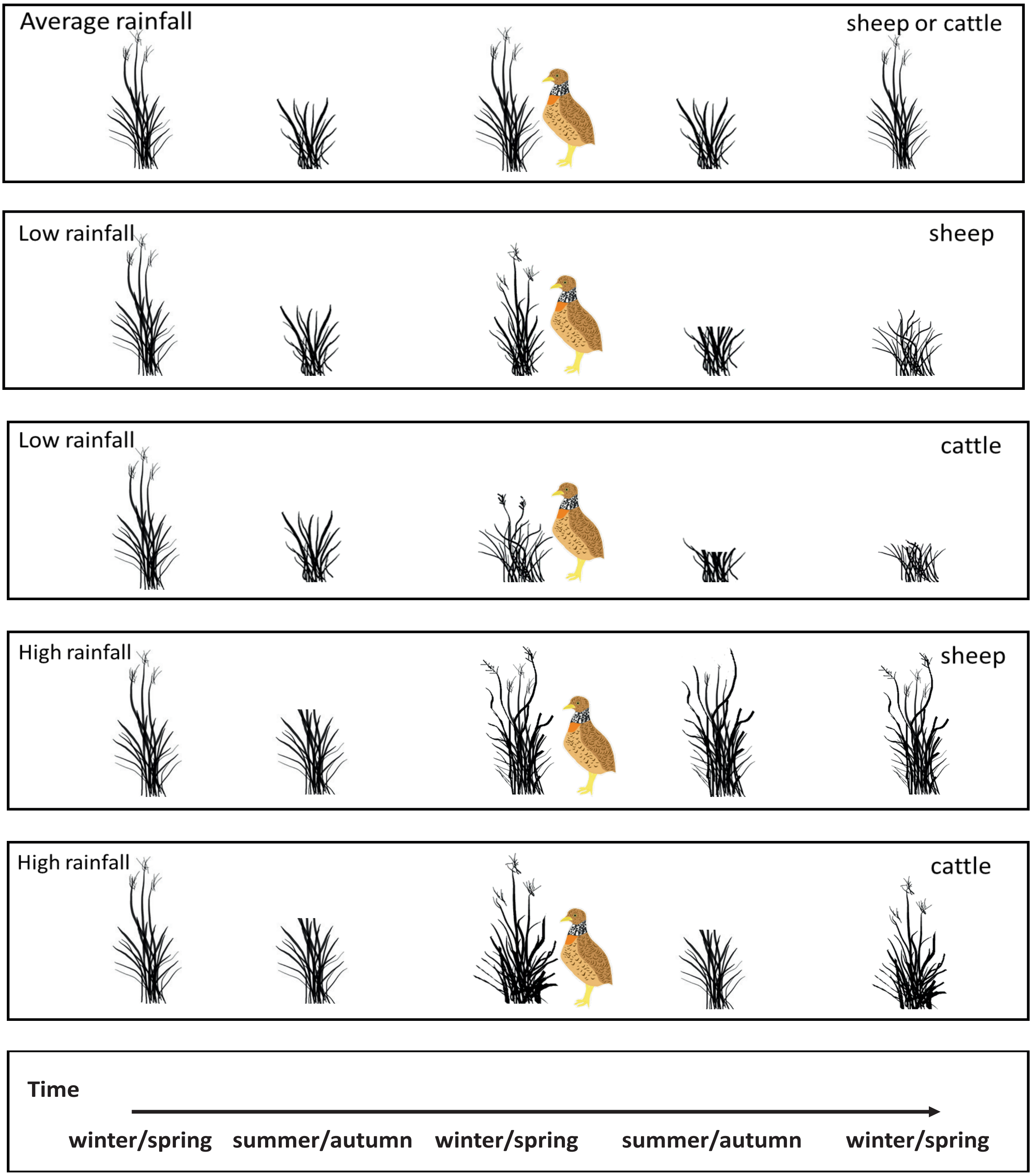


Figure 17. Conceptual model of growth of an individual grass tussock under different climate scenarios subjected to sheep or cattle grazing over time. The grass tussock represents an individual C3 species that during average rainfall undergoes growth and flowering in winter and spring, and dormancy through summer. A, average rainfall; sheep or cattle grazing can produce similar grass structure. B, low rainfall and sheep grazing; tussock size decreases over time as growth and flowering is reduced, but they remain large enough to provide cover for Plains-wanderer. C, low rainfall and cattle grazing; tussocks are subjected to greater grazing pressure, relative to sheep grazing, and their size decreases further, leaving little cover for the Plains-wanderer. D, high rainfall and sheep grazing; tussock size increases through time as new growth is added faster than older leaves can be consumed through grazing. E, high rainfall and cattle grazing; tussock size remains relatively stable as growth of leaves and their subsequent consumption by cattle reach an equilibrium. Illustrated Plains-wanderers are for scale.

THE ROLE OF FIRE AND GRAZING IN HABITAT MANAGEMENT AND RESTORATION FOR GRASSLAND BIRDS 04

Grasslands are the most heavily exploited ecosystem for human land use on the globe. Consequently, they are also one of the most degraded and endangered ecosystems. Restoration of grasslands at scale is imperative to prevent the ongoing loss of species and disruption of ecosystem services.

Following decades of cultivation, fertiliser addition and inappropriate grazing regimes, native grasslands on the Northern Plains of Victoria occur in a range of degraded states. Periodic low-intensity livestock grazing has continued in recently acquired nature reserves based on the premise that past grazing management had produced the current grassland community and maintaining that regime (the status-quo) should maintain the current biota, including important populations of threatened species (Foreman 2010). Some evidence exists to support this assumption, but status quo grazing has not been assessed alongside possible alternative disturbance types that could function as biomass management tools and assist recovery of key grassland features such as biological soil crusts and native herb and invertebrate diversity. Furthermore, there has been no direct investigation of the effects of status-quo grazing on birds, food resources or vegetation composition.

Many different strategies or types of disturbance can be used to manage biomass accumulation and vegetation structure in grasslands for biodiversity conservation. Historical disturbance types are often a first choice for grassland management because of the evolutionary exposure of biota to such processes. Fire applied by Indigenous Peoples as a tool for managing Country, as well as wildfire, are postulated to have played a role in shaping the evolution of the Northern Plains Grasslands community. The reintroduction of planned fire into this system could assist efforts to manage biomass accumulation and create structural heterogeneity. However, it remains unclear if severe habitat degradation and state shift has impacted the ability of species to respond positively to fire. Crash grazing (also known as pulse grazing) is often promoted as a more ecologically friendly approach to grazing of native vegetation, the theory being that by forcing grazers to consume both highly palatable (and often grazing-sensitive) and less palatable plant species, and affording perennial plants sufficient time between disturbance events to recover from grazing impacts, more species-rich vegetation communities can be maintained (Dorrough et al. 2004).

Exclusion of disturbance can advantage plants that are sensitive to frequent defoliation and fauna that prefer dense stands of vegetation. Although disturbance exclusion is unlikely to be an appropriate strategy over an extended period for grassland management, short-term rest (1-2 years) from frequent disturbance, particularly in dry or drought years, may afford disturbance-sensitive species an opportunity to successfully reproduce. It may also facilitate the maintenance of tussock structure important to fauna during drought.

A Mixed-disturbance Type Approach Is Needed For Habitat Management And Restoration Of Northern Plains Grasslands

Our study found that different types of disturbance produced both positive and negative outcomes for grassland bird species and habitat attributes (Nugent et al. 2022d). We found crash grazing and fire produced more open, shorter swards, with less exotic grass cover, compared to status-quo grazing or disturbance exclusion (Figure 19). Preferred habitat structure for the Plains-wanderer was maximised by status-quo grazing. Grassland birds responded in opposing ways to a disturbance switch. Brown Songlarks and Horsfield's Bushlarks responded positively to disturbance exclusion, while Stubble Quail responded negatively to crash grazing. Australasian Pipits were highest in response to status-quo grazing. Our findings suggest that a mix of different types of disturbance could be used if the aim is to promote the spectrum of vegetation structure and food sources required to support a diverse grassland bird community and restore native grasslands.

Management of the grassland conservation network must consider the present needs of biota, as well as improving the trajectory of ecosystem resilience. In some instances, balancing these two objectives may not be possible and different management strategies will need to be applied at appropriate spatial scales.

Decisions to institute burn regimes for conservation purposes must consider that grasslands exist in a degraded state in a highly modified landscape. Where historically birds would have moved across landscapes to find their preferred habitat in a specific state of post-fire recovery, the present-day isolation of many reserves and scarcity of remnant grassland means burns should be planned with an aim of limiting the likelihood of individuals being displaced by a lack of resources in the immediate post-burn environment. This may be achieved by applying low-intensity, fine-grain fire across an area no larger than the home-range of focal species (i.e mean Plains-wanderer home range = 32 hectares (Chapter 2)). In scenarios where planned fire is not possible (i.e. due to operational constraints or a high-density of threatened fauna), crash-grazing may be an effective substitute.

Figure 18. An ecological burn in native grassland within Terrick Terrick National Park conducted by land management agencies, Parks Victoria and Victorian Department of Environment, Land, Water, and Planning. Photo credit, Ben Hodgens.

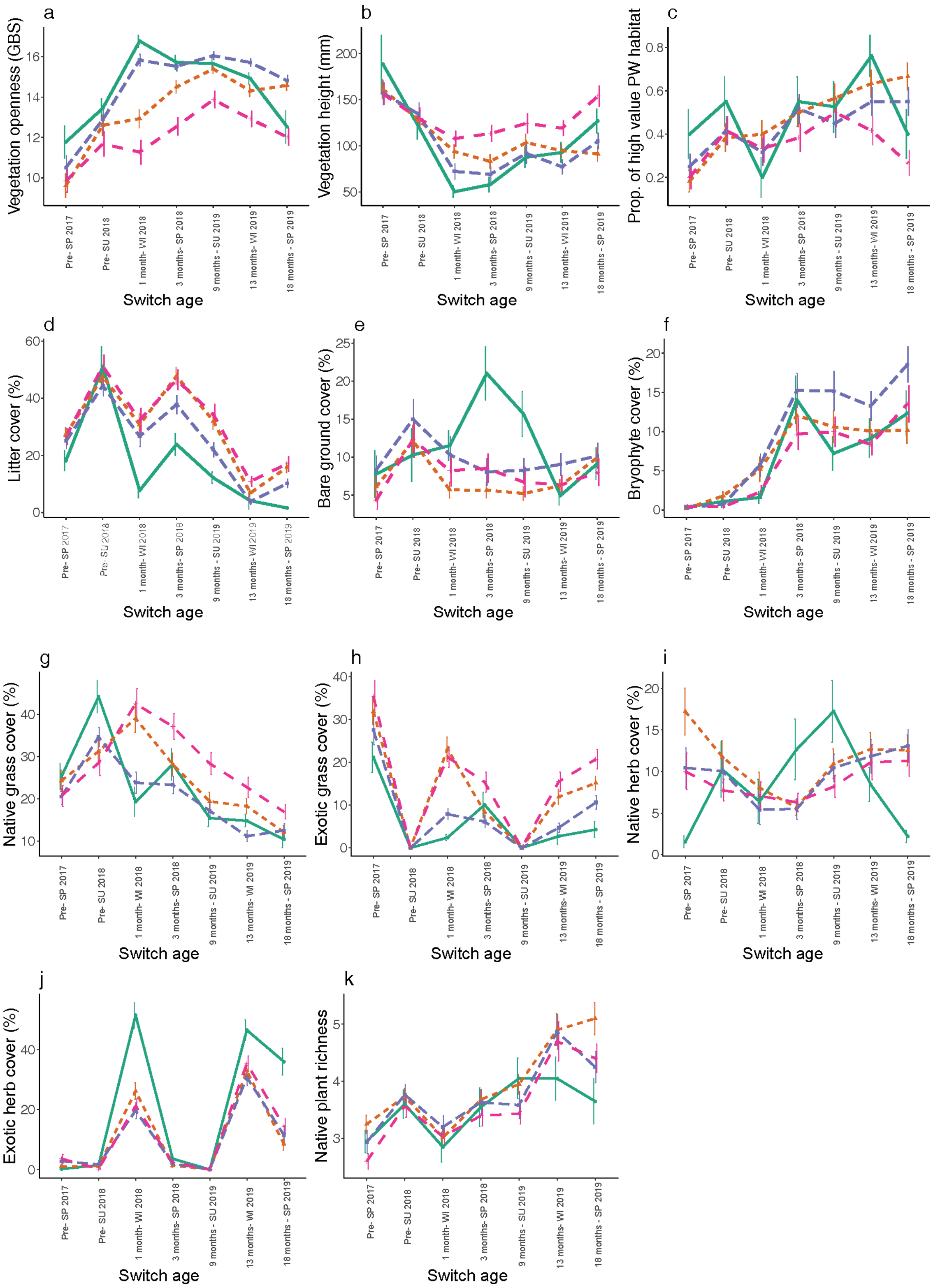


Figure 19. Responses of vegetation attributes to different disturbance types across the study period, spring 2017-spring 2019. Green solid line represents the planned fire treatment (n = 2). Orange short-dashed line represents status-quo grazing (n = 6). Purple long-dashed represents crash grazing (n = 6). Pink long-dashed line represents disturbance exclusion (n = 6). Treatments were first implemented in early winter 2018 (first vertical dotted line). A second crash-grazing event occurred in early winter 2019 (indicated by the second vertical dotted line). Bars indicate standard error.

Study approach: investigating the effects of different disturbance types on grassland birds and habitat

We used a before-after-control-impact experiment to assess the effects of different disturbance types on grassland birds, vegetation structure and food resources over a 3-year period. In total, six sites were selected: four in Terrick Terrick National Park and two in Bael Bael Grasslands Nature Conservation Reserve. At each site, three or four six-hectare plots (300 m long, 200 m wide) were positioned at least 200 m apart in areas of predominately red soil. The size of plots was designed to match a scale that birds will respond, as well as readily inform decision-making of land managers. Plots were assigned one of four different management strategies (i.e. treatments): 1) planned fire (single event; Figure 20), 2) crash-graze by sheep (two events; Figure 21), 3) management exclusion or 4) status-quo grazing (control). All four treatments were applied at two sites. At the remaining four sites, only grazing treatments (i.e. no planned fire) were applied. Birds, vegetation structure and food resources were surveyed seven times across the study period: two occasions pre-treatment and five post-treatment.

Figure 20. A planned burn experimental plot 2-weeks post-fire. Burns were conducted in early winter 2018.

Figure 21. Temporary electric fences were used to control the movements of livestock in grazing experiments. This photograph demonstrates vegetation structure typical of crash-grazed plots following a grazing event (right-side of fence). The cover of exotic grasses (visible as the green tinge occupying inter-tussock space on the left-side of the fence) was significantly lower in crash-grazed plots compared to status-quo grazing plots.

Figure 22. Changes in vegetation structure typical of a response to a switch in disturbance type to a) planned fire, b) disturbance exclusion, c) crash-grazing and d) status-quo grazing.

Implications For Practice

Multiple different types of disturbance could be applied at varying spatio-temporal scales if the aim is to meet the diverse habitat needs of all fauna and restore degraded grasslands

Status-quo grazing supports the maintenance of habitat structure for the Plains-wanderer but does not maximise the availability of food

Plant and seed addition are likely needed to deliver an increase in native plant diversity during a switch from status-quo grazing to an alternate disturbance type

Fire and crash-grazing can be useful tools for reducing the cover and seed abundance of exotic grasses

Areas of disturbance exclusion in years of low rainfall can benefit bird species that are dense-vegetation specialists

Research For The Future

Understanding how different disturbance types affect biota following multiple treatments and across different climate cycles is important to inform decision-making by land managers. Our study provided insight into the short-term effects of a disturbance switch on grassland birds and habitat, but not longer-term impacts. Future studies should seek to answer: what are the long-term effects of a switch from status-quo grazing to an alternate disturbance type for grassland birds and their habitat?

The spatial and temporal configuration of habitat influences its suitability for single species and communities supporting species with different habitat preferences. Our study highlighted that no one disturbance type will benefit a single species, so a key question is what is the optimal configuration of different disturbance types and regimes at patch- (1-50 ha), reserve- (100-300 ha) and landscape-scales (>300 ha)?

Because Plains-wanderers were absent (or at least at very low densities) at our management trial sites, we were unable to determine the direct effects of different disturbance approaches on the Plains-wanderer. It is therefore important that future studies seek to answer the question: how do pulse disturbances such as crash-grazing or planned fire impact the Plains-wanderer during and following an event?

Figure 23. Incidental observations found disturbance exclusion supported more flowering of Billy Buttons *(Pycnosaurus globulus)* (top-left) and Feather-heads *(Ptilotus macrocephalus)* (top-right). Brown Songlarks, a dense vegetation specialist, responded positively to disturbance exclusion (bottom-left), while Australasian Pipit, a generalist, responded positively to status-quo grazing (bottom-right).

CHALLENGES FOR THE FUTURE

05

Despite the global conservation significance of the Plains-wanderer, its future remains highly uncertain. The compounding threats of a changing climate and ongoing habitat loss and degradation are set to increase the difficulty of managing habitat and populations of the species. Australia's current environmental laws are failing to prevent conversion of native grasslands to cropping, which impacts the overall amount and connectivity of suitable habitat. Such landscape changes likely make courtship for the Plains-wanderer more difficult as birds are postulated to form loose congregations of breeding birds. In addition, habitat fragmentation likely increases the impacts of invasive predators by facilitating movement corridors and the creation of more harbour for foxes and cats. Inappropriate disturbance regimes are also a key threat to the Plains-wanderer. As the climate for many parts of Australia, including the Northern Plains of Victoria, are projected to experience more intense droughts and flooding rains in coming decades, maintaining habitat structure within an optimal range will become more challenging. Combating this myriad of threats requires evidence-based management interventions and appropriate policy development.

Figure 24. Major rainfall events associated with La Nina climate cycles cause widespread floods, directly impacting ground-dwelling fauna and driving rapid grass growth.

Reasons for Hope

06

There are many reasons to be optimistic about the future of the Plains-wanderer. First, a diverse range of passionate stakeholders including farmers, community members, land managers and researchers are leading conservation efforts and having meaningful on-ground impacts. The amount of private grasslands protected through conservation covenants that prevent cropping and overgrazing continues to grow, as well as awareness of the Plains-wanderer's plight among the local and wider community.

For many graziers on the Northern Plains, the occurrence of Plains-wanderers on their farm is an indicator of good land management and a source of pride. In addition, numerous local environmental community groups champion the interests of the Plains-wanderer in the management of public land. Within government land management agencies, there is support for trials of alternative biomass management strategies and active restoration activities.

Relative to some other critically endangered species, successful conservation of Plains-wanderer in Victoria could be seen as straightforward: stop grassland destruction, allow flexible grazing and other disturbance regimes and limit the impacts of invasive predators. The unique breeding biology of the Plains-wanderer (mature at four-months of age and capable of breeding in most months of the year) places the species in a position where a population can substantially grow across a relatively short period under favourable environmental conditions.

In the early 1900s, D'Ombrain (1926) warned in an aptly named paper, "The Vanishing Plains-wanderer" that we must not sit idle "while it (the Plains-wanderer) fades out before our eyes" if we want to "retain this vanishing species". For almost 100 years, these concerns, as well as those of many others, have largely gone ignored by governments and we find the Plains-wanderer at the edge of extinction. However, there is still time to act to prevent this dire outcome. With effective action, the distinctive call of the Plains-wanderer may once again be commonly heard across vast areas of the grassy plains of northern Victoria.

Figure 25. A high-quality, herb-rich native grassland that supports a profitable sheep production enterprise on the Northern Plains of Victoria. Grasslands are a unique ecosystem that need active management and stewardship to maintain their function.

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Figure 26. Sunset on the Northern Plains of Victoria.

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