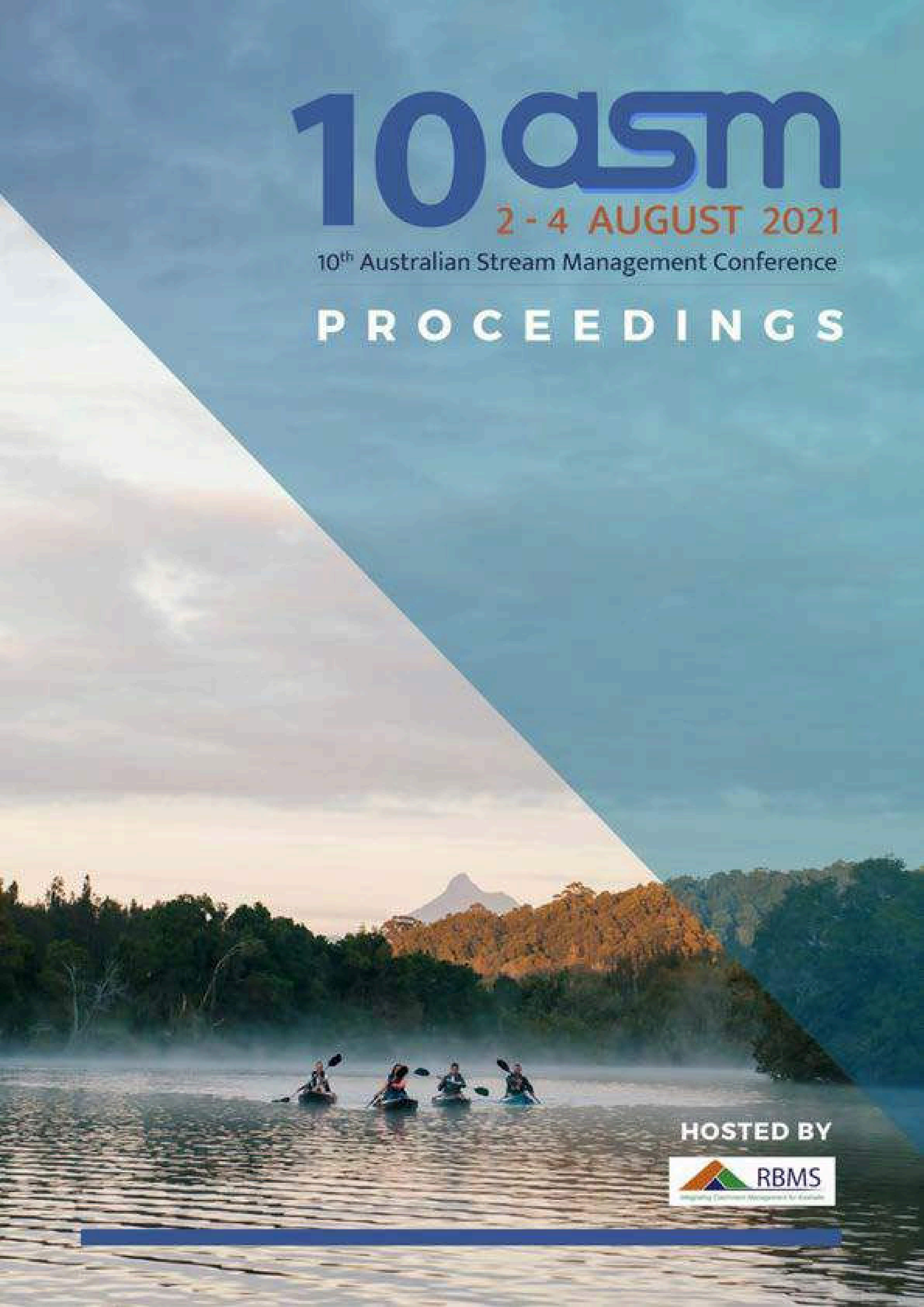

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Applying a bird's eye view to environmental water planning

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Key Points

- Landscape scale planning will improve outcomes for environmental watering and other NRM activities.
- Colonial nesting waterbirds use a variety of wetland habitats throughout their life cycle and management interventions need to address those requirements in a coordinated way
- Environmental water can only influence a small proportion of waterways within a region, to be effective environmental water planning should be coordinated with other strategic interventions, including innovative management of wetlands that are used as water supply storages.

Abstract

Environmental water planning and management has traditionally focused on identifying watering needs at individual wetlands or rivers, but many ecological processes operate at larger spatial scales. To achieve many of our stated environmental watering objectives we need to take a broader landscape-scale approach and consider the combination of watering actions (and other interventions) that need to be coordinated across multiple waterways, including waterways that are not traditionally managed for environmental outcomes.

Using Royal Spoonbills (*Platalea regia*) as a test case, we asked what combination of wetlands need to be managed across northern Victoria to grow colonial nesting waterbird populations. Potential limiting factors for spoonbill populations are the number of suitable breeding sites and the availability of suitable food and shelter for juveniles. GIS analysis suggests that while northern Victoria has suitable resources for spoonbills in flood years, the quality and quantity of resources quickly diminishes in subsequent dry years.

These results can be used determine the number and type of wetlands to actively manage in the first few years after large scale natural breeding events to achieve desired outcomes for Royal Spoonbills and other colonial nesting waterbirds.

Keywords

Landscape scale planning, wetlands, Royal Spoonbills, environmental water

Introduction

Many waterway rehabilitation programs, including environmental water planning and implementation, have historically focused on individual river reaches and individual wetlands. Program planning typically starts with a site (i.e. river or wetland) and its associated environmental values (e.g. flora and fauna), and asks what action is needed to 'improve' the health or condition of the site to support those values. Site-based management programs often focus disproportionately on high-profile outcomes (e.g. applying environmental water to support waterbird nesting and chick fledging) without considering whether that outcome alone is sufficient to achieve a broader environmental objective (e.g. to grow regional waterbird populations).

Local scale (sensu Wiens, 1989) management approaches have been instrumental in gaining community support for various natural resource management (NRM) programs and are an effective way to address some environmental objectives (for example managing populations of nationally endangered Murray Hardyhead in discrete wetlands). However, the proliferation of local scale management plans has resulted in a patchwork of disparate management actions targeting different objectives in different waterways (Sharpe, 2018).

Many of the environmental objectives identified in state and federal NRM programs are underpinned by ecological processes that vary in importance throughout a species' life cycle and operate at large spatial scales (Lake et al., 2007). Local, site-based management approaches that do not adequately consider ecological processes that operate beyond the managed site boundary are likely to fail. Moreover, having a patchwork of disparate management actions within a region may mean that intervention activities at one site have a detrimental effect on a different set of environmental objectives at other nearby sites.

We propose that effective waterway rehabilitation programs need to consider the physical and ecological processes that limit the achievement of key environmental objectives and implement interventions at spatial and temporal scales that match those underlying processes. In many cases this will require coordinated intervention across multiple waterways.

This paper briefly describes a trial conducted in northern Victoria to develop and test an approach to plan NRM activities across multiple waterways to achieve specific environmental objectives. The trial focusses on a single objective (i.e. to grow Royal Spoonbill populations across northern Victoria) as a proof of concept. It is hoped that the approach will ultimately be extended to include multiple environmental objectives.

What NRM interventions are considered?

The trial primarily focused on environmental water management and specifically considered what combination of wetlands need to be watered across northern Victoria to support Royal Spoonbill populations. In doing this, it is necessary to consider what ecosystem services are already present in the landscape and hence what resource gaps environmental watering will aim to address. We also consider what complementary actions may be needed, especially at managed water storages within the study region, to improve the quality of environmental resources at sites that will not receive environmental water. It is expected that the approach will help environmental water holders and waterway managers decide how available water holdings should be used across multiple wetlands over multiple years.

Why focus on waterbirds and in particular Royal Spoonbills for the trial?

Waterbirds were selected as the focus of the trial because: increasing waterbird populations is a key objective of the Murray Darling Basin Plan (MDBA, 2019), they select habitats at a landscape scale, they are responsive to environmental change (Reid et al., 2013), are able to be surveyed in meaningful numbers for analysis, are of societal interest and Australia has legal obligations to protect certain species (e.g. under the Ramsar Convention). Royal Spoonbills are a particularly good indicator because they are completely reliant on waterways (as opposed to other environments) for nesting, feeding and refuge. Moreover, providing the relevant physical and ecological requirements for spoonbills will likely satisfy the requirements for other waterbirds including egrets and ibis.

Conceptual understanding of factors affecting Royal Spoonbill populations

Royal Spoonbills occur throughout Australia, but their strongholds are in the Murray-Darling Basin and eastern Australia. They also occur and breed in small numbers in parts of New Zealand and are occasionally recorded as vagrants in other Pacific islands, New Guinea and Indonesia (Marchant and Higgins, 1990). Royal Spoonbill population dynamics are primarily driven by the availability and quality of habitat and food. These factors together with a range of mortality drivers such as disease, toxins and predation interact to determine individual condition, growth, survival, movement and breeding.

Royal Spoonbills require breeding, foraging, roosting, movement and refuge habitats to complete their life cycle and maintain populations. Breeding habitats, are typically freshwater or brackish wetlands that hold water at least 0.5-1.5 m deep for more than six months and have tall reeds, rushes, lignum or shrubs for nesting (Marchant and Higgins, 1990). Foraging habitats can include shallow (< 0.4 m deep) ephemeral, temporary or permanent wetlands that have aquatic or emergent vegetation or submerged logs that shelter prey (Marchant and Higgins, 1990). Royal Spoonbills commonly roost in trees or shrubs at or near foraging sites (Marchant and Higgins, 1990).

Individuals can travel long distances of 100s to 1000s of kilometres relatively rapidly, usually at night (McGinness et al., 2019) and require foraging and roosting habitats to safely rest and refuel along their journey. Recent research suggests that Royal Spoonbills forage close to their nest (average distance 4 km) when raising chicks and slightly further (average distance 6 km) from their roost when not nesting (McGinness et al., 2019).

In fresh water, Royal Spoonbills eat mainly fish, yabbies and aquatic invertebrates, but also take frogs, tadpoles and molluscs (Marchant and Higgins, 1990). Food intake has been estimated at c. 1900 prey/day (Howard and Lowe, 1984) and the total food energy needed to raise a single Royal Spoonbill chick from hatching to 50 days has been calculated as ~71,290 kJ (O'Brien and McGinness, 2019). For a nesting event of 1000 nests producing three chicks per nest, this is the equivalent of ten tonnes of yabbies or eight tonnes of small fish. It does not include the food required by the nesting adults or by juveniles older than 50 days (O'Brien and McGinness, 2019).

It is likely that river regulation, water abstraction, and other water resource development activities have resulted in changes in Royal Spoonbill habitat and food availability, particularly for breeding and foraging. Consequently, environmental water is often used to support the completion of breeding events, allowing chicks to grow and leave the nest. But despite some successful breeding events (e.g. in response to natural floods in 2011), populations have apparently failed to grow. Possible reasons for this include insufficient breeding frequency or event size, or low survival (particularly among juveniles) between breeding events. These may be driven by lack of habitat; insufficient food; pollution; predation or the effects of invasive species.

In this trial, we explored the availability of breeding and foraging habitats for Royal Spoonbills in northern Victoria, and how environmental water might be used to supplement these habitats.

Methods

The trial was a GIS analysis that comprised two main parts: 1) a comparison of Royal Spoonbill presence and breeding records across northern Victoria against the distribution of potentially suitable habitats across northern Victoria, and 2) a temporal assessment of the availability of suitable Royal Spoonbill habitats in the North Central Catchment Management Authority (CMA) region of northern Victoria from 1999 to 2018.

All data layers selected for the analysis are readily available and have uniform coverage over northern Victoria or the North Central CMA region. The methods for each part are described below.

Part 1 – Comparison of Royal Spoonbill presence and breeding records against suitable habitat distribution in northern Victoria

This assessment included the following steps:

- Royal Spoonbill presence and breeding was mapped across northern Victoria using data sourced from the Murray-Darling Basin Authority and the Atlas of Living Australia (DOI https://doi.org/10.26197/5ec725e0c6e9a), and checked by Victorian CMAs and waterbird experts.
- Potential Royal Spoonbill breeding and foraging habitats were mapped using combinations of attributes and attribute thresholds (such as water depth, wetland size, inundation duration, type and extent of wetland vegetation) that were informed by the literature and expert opinion.
- Royal Spoonbill records were compared against the mapped habitats to confirm that the GIS analysis selected sites where spoonbills have been observed and to determine the number and distribution of potential breeding and foraging sites where Royal Spoonbills have not yet been recorded.

Part 2 – Temporal assessment of the availability of suitable Royal Spoonbill habitat in the North Central CMA region.

The temporal assessment focused on the North Central CMA region, which has the greatest number of confirmed Royal Spoonbill breeding and foraging sites in northern Victoria. This assessment:

- used the results of Part 1 to identify specific wetland types (based on the Corrick and Norman (1980 classification) that were likely to provide suitable breeding and or feeding habitat for Royal Spoonbills,
- determined how many of those wetland types were present within 50 km of the known Royal Spoonbill breeding sites, and
- used a region wide flooding layer to determine the inundation history of each of those wetlands from 1999 to 2018.

The main purpose of this assessment was to determine how many and what types of wetlands, and hence resources were available for Royal Spoonbills each year based on the prevailing climatic conditions. The analysis identified the number of seasons that wetlands held water after natural flooding events as well as the influence of environmental watering and operational use of water storages where relevant.

Both analyses were constrained by the nature of available datasets at the scales required. For example, the extent to which the available GIS layers accurately described wetland attributes that are important to Royal Spoonbills was variable. In particular, available datasets did not reliably estimate water depth and inundation duration at individual wetlands over time, and in some cases, datasets were unable to indicate the proportion of a wetland that was likely to have suitable habitat.

Results

Royal spoonbills have been formally recorded at 383 locations across northern Victoria since 1889, but at only 103 locations since 1990 (Atlas of Living Australia 2020, DOI https://doi.org/10.26197/5ec725e0c6e9a). Most of these records relate to foraging or roosting birds. In northern Victoria, nesting has only been recorded at nine sites within four wetland complexes: the Kerang wetlands (NCCMA); Kow Swamp (NCCMA); Barmah Forest (GBCMA) and wetlands near Wodonga on the Murray River (NECMA).

The GIS analysis for Part 1 identified 1075 wetlands across northern Victoria that may have suitable foraging habitat and 69 wetlands that may provide suitable breeding habitat (see **Figure *1***). Alignment between wetlands with predicted foraging habitat and wetlands where Royal Spoonbills had been observed was high (success rate 80-91%). However a large number of wetlands with the attributes of potential Royal Spoonbill foraging habitat had no records of Royal Spoonbills present since 1990 (**Figure *1***). Approximately 80% of these potential foraging wetlands are classified in the Victorian inventory as seasonally, intermittently, or ephemerally inundated wetlands. This result suggests that the GIS analysis is correctly identifying potential feeding sites, even if only a relatively small proportion of those are being surveyed or used. An additional 38 sites to those already known were identified as potential breeding sites given suitable flood conditions. Only five of the nine known breeding sites in northern Victoria were identified as having suitable attributes for Royal Spoonbill breeding. This discrepancy was due to unreliable estimates of wetland inundation period at sites with high vegetation cover in the Astron Landsat data analysis (DELWP, 2019).

The GIS analysis for Part 2 demonstrated the availability of potential Royal Spoonbill breeding and foraging habitat across the North Central region between 1999 and 2018 assuming required habitat functions were provided when water was present (Table 1). The first decade of available data coincided with the Millennium Drought, when the Loddon River system reservoirs dried, and the river stopped flowing. Floods in 2011-12 and 2016-17 filled many wetlands across the region but intervening years had low rainfall. Harvesting of upper catchment flows within reservoirs and modifications to the floodplain (e.g. levees channels and roads) that act as barrier to natural flows prevented minor to moderate inundation that would have otherwise occurred in these intervening years at some wetlands within the study area.

Figure 2 and Figure 3 show the decline in available habitat compared to the total area of wetlands by wetland type within 50 km of key breeding habitat. The wetland types least represented outside major flood years are temporary (saline and freshwater) swamps, temporary marshes and meadows. Temporary freshwater swamps account for nearly half of the wetland habitat (by area) across the North Central region during flood years, but 50% of them completely dry one year after inundation and 95% of them are completely dry within two years (see Table 1).

Most of these temporary swamps, marshes and meadows across the floodplain would be expected to fill frequently without flow regulation and have specific attributes (i.e. shallow water, with submerged and emergent vegetation) that make them potentially important foraging sites for Royal Spoonbills (and other waterbird species).

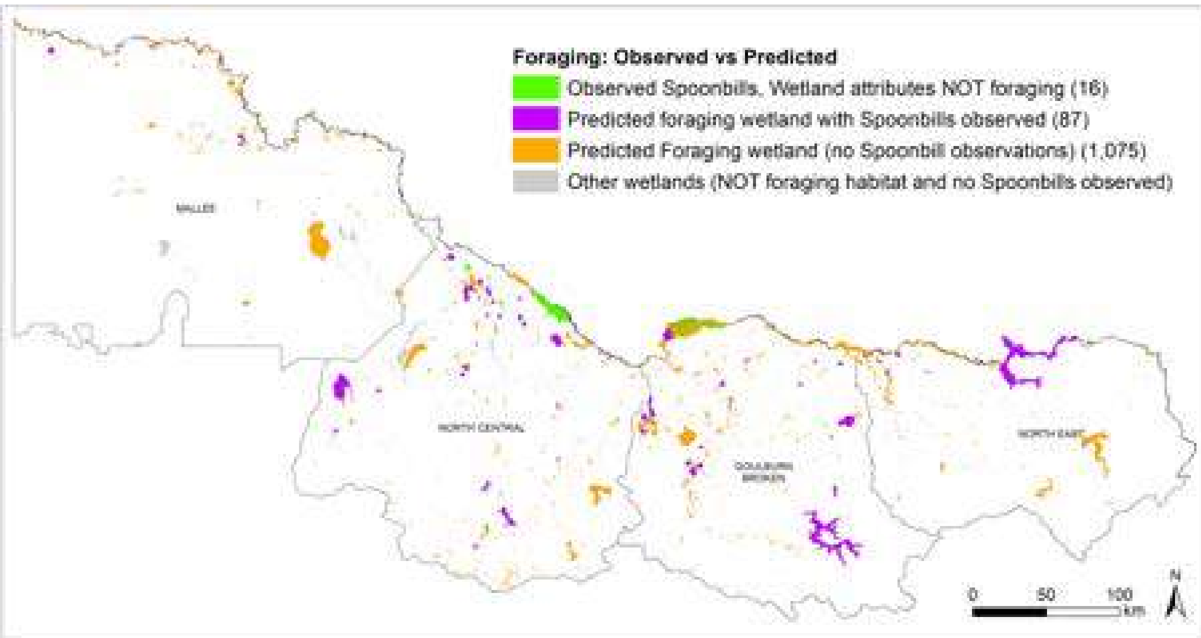

Figure 1: Map showing wetlands across northern Victoria that are predicted to have suitable foraging habitat for Royal Spoonbills, and wetlands where Royal Spoonbills have been observed foraging in at least 3 months since 1990.

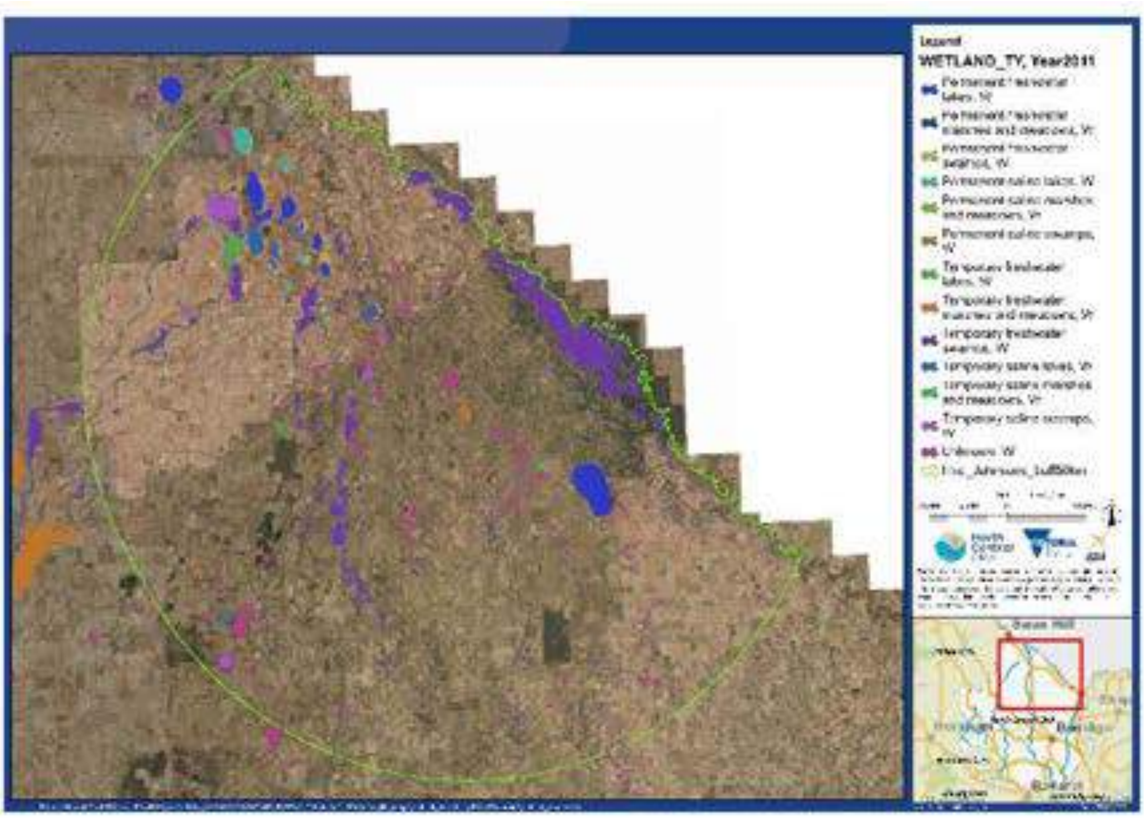

Figure 2: Available wetland habitat within the North Central CMA region in 2011, immediately after widespread flooding.

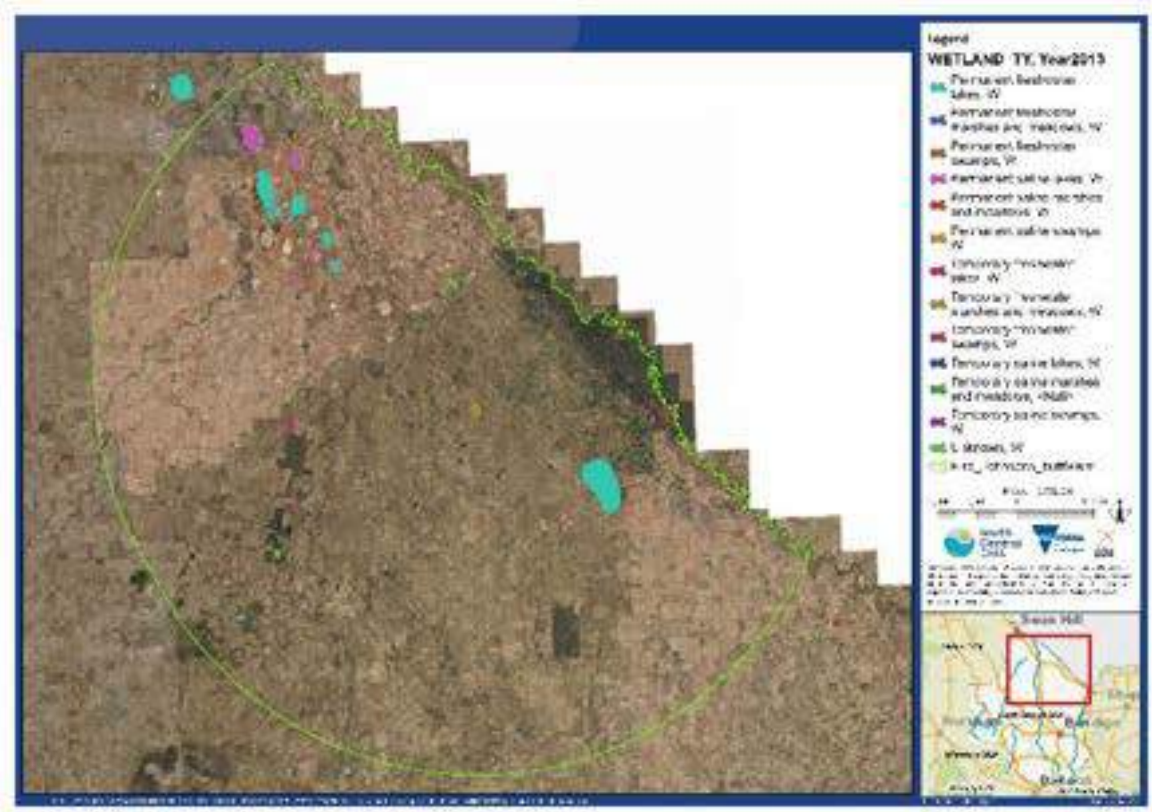

Figure 3: Available wet habitat in 2013, two years after widespread flooding.

Table 1: Area (ha) of wetland habitat by wetland type available within a 50 km radius (northern boundary is Murray River) to wetland dependant species over 20 years from 1999 to 2018.

Wetland type (as per state wetland current spatial data)	Total Area (ha)	Year1999	Year2000	Year2001	Year2002	Year2003	Year2004	Year2005	Year2006	Year2007	Year2008	Year2009	Year2010	Year2011	Year2012	Year2013	Year2014	Year2015	Year2016	Year2017	Year2018
Permanent freshwater lakes	**5,140**	5,128	5,128	5,128	5,128	5,128	5,128	5,140	5,140	5,128	5,128	5,140	5,140	5,140	5,140	5,140	5,128	5,140	5,140	5,140	5,128
Permanent freshwater marshes and meadows	**90**	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Permanent freshwater swamps	**196**	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196
Permanent saline lakes	**1,433**	1,252	1,252	1,252	1,252	1,252	1,252	1,346	1,346	1,346	1,346	1,346	1,346	1,433	1,393	1,346	1,346	1,346	1,346	1,346	1,346
Temporary freshwater lakes	**1,142**	51	51	51	51	51	51	51	51	51	51	51	1,068	1,142	1,073	289	226	226	1,068	1,068	51
Temporary freshwater marshes and meadows	**2,202**	56	56	56	56	56	56	97	442	97	97	97	581	1,837	445	442	445	97	581	442	100
Temporary freshwater swamps	**22,853**	1,119	1,119	1,119	1,119	1,119	1,119	1,250	1,198	1,142	1,142	2,776	17,082	20,999	10,640	1,119	9,658	1,193	17,096	1,931	9,658
Temporary saline marshes and meadows	**1,518**	9	9	9	9	9	9	9	638	638	9	9	638	1,513	701	9	9	9	638	638	638
Temporary saline swamps	**1,931**	17	17	17	17	17	17	17	17	17	17	17	266	1,922	1,823	17	17	17	266	266	17
Unknown	**12,065**	510	510	510	510	510	510	1,268	547	547	689	735	2,949	10,579	2,728	799	1,451	1,154	2,754	1,939	957
Total inundated wetland area (ha)	**48,571**	**8,429**	**8,429**	**8,429**	**8,429**	**8,429**	**8,429**	**9,465**	**9,667**	**9,252**	**8,765**	**10,458**	**29,357**	**44,852**	**24,230**	**9,448**	**18,566**	**9,468**	**29,176**	**13,058**	**18,181**

Discussion

In flood years there are likely sufficient resources for Royal Spoonbills in northern Victoria, but the quality and quantity of resources diminishes in subsequent dry years meaning there is potentially not enough resources to allow juvenile birds to survive and thrive. This supports the hypothesis that Royal Spoonbill populations, and by extension populations of other colonial nesting waterbirds that have similar requirements, are limited by food and habitat resources that are needed to ensure juvenile birds survive and become breeding adults.

Current environmental water management for colonial nesting waterbirds focusses on maintaining water levels at breeding wetlands following naturally triggered nesting events to maximise the number of chicks that are successfully fledged. The relatively low number of wetlands where Royal Spoonbills breed in northern Victoria and relatively low frequency of breeding events suggests that the current environmental watering strategy should remain a high priority. But our analysis suggests that an equally high priority will be to deliver environmental water to potential high-quality feeding wetlands in the two to three years after natural breeding to ensure there is sufficient food and shelter for juvenile birds. This environmental watering should target temporary swamps, marshes and meadows because they are likely to provide appropriate food and foraging habitat for juvenile birds and they are usually under-represented across northern Victoria (at least in the North Central region) in dry years.

Some of the sites targeted for watering in the years after natural breeding may not be the same as the breeding sites. Moreover, it may be important to water different sites in successive years because inundating wetlands that have been dry for a year is likely to stimulate productivity, which may increase the quality and quantity of food for foraging birds.

Environmental watering alone is not likely to provide sufficient habitat and food resources to grow Royal Spoonbill populations. In dry years, permanent lakes and water storages account for much of the standing water across northern Victoria, but these sites often provide limited high-quality habitat and food for colonial nesting waterbirds. Innovative management of these permanent waterways, such as introducing habitat complexity, varying water levels to encourage the growth of more diverse riparian vegetation and to promote greater nutrient and carbon cycling, will likely improve resources for waterbirds and other native biota and therefore complement planned environmental watering.

Conclusion

The approach described in this paper is yet to be applied to inform the use of environmental water or other complementary management actions. However, it has identified types of wetlands where environmental watering or other management interventions could increase the quality and quantity of food for juvenile Royal Spoonbills and provide protection from predators. It is suggested that appropriate interventions at these sites will significantly improve the recruitment of juvenile Royal Spoonbills into the breeding population and therefore over time will stabilise and hopefully increase the population across northern Victoria and beyond. Some of the wetlands identified through this approach are unlikely to be identified for priority intervention activities under the normal site-based planning approaches, which tend to focus on larger more permanent waterways.

The approach also allows us to consider whether proposed management interventions are likely to have a meaningful effect on our overall objective. For example, we could calculate the total amount of additional environmental resources (in this case foraging habitat and potentially available food) that are provided by proposed environmental watering actions and other management interventions at the selected sites and qualitatively or quantitatively estimate whether that increase is likely to significantly improve Royal Spoonbill recruitment and overall population viability. This is an important, but often neglected, question to ask of any planned intervention program.

Our trial focused on a single species with relatively well understood environmental requirements. Environmental management aims to address multiple objectives and therefore the next challenge will be to scale-up the approach to determine the combination of management actions coordinated across a range of programs and waterways to achieve outcomes for multiple species and objectives.

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