26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Toward long-range forecasting of ecological outcomes

David E Robertson[a], Jin Teng[b], Jorge L. Peña-Arancibia[b], Andrew Schepen[c], Heather McGinness[b], Micha V. Jackson[b], Catherine Ticehurst[b], Andrew Freebairn[b], Ashkan Shokri[a]

[a] CSIRO Environment, Clayton, Victoria, Australia, [b] CSIRO Environment, Canberra, Australian Capital Territory, Australia, [c] CSIRO Environment, Brisbane, Queensland, Australia
Email: David.Robertson@csiro.au

Abstract: Annual environmental water planning requires a range of risks and opportunities to be considered. We develop a framework for long-range forecasting of ecological outcomes and evaluate the components that can be readily implemented for two RAMSAR-listed wetlands in the Murray-Darling Basin. We show that ensemble forecasts of floodplain inundation can be skilful to lead times of many months and tend to be more skilful than rainfall and runoff forecasts for the wetlands investigated. We also identify opportunities for translating forecasts of wetland inundation to the likelihood of achieving ecological outcomes such as waterbird breeding events.

Keywords: *Seasonal climate and streamflow forecasting, remote sensing, inundation forecasting*

1. INTRODUCTION

Environmental water in the Murray-Darling Basin is managed to supplement natural river flows and support ecological outcomes, such as waterbird breeding and fish spawning. Planning of environmental water use occurs at multiple time scales. Annual water management plans link environmental priorities with risks and benefits of environmental water delivery. The risks facing environmental water managers are diverse and include the influence of prevailing climate conditions on water availaiblity and environmental demands, constraints on water delivery, and indirect risks such as that posed by a high pathogenicity avian influenza. Environmental water managers would benefit from any available insights into these conditions over the coming seasons in developing annual watering plans.

Existing seasonal forecast products can potentially assist with understanding water availability over the coming season. Methods to produce skilful forecasts of catchment runoff to lead times of 12 months have been deployed operationally by water managers in Australia (Matala et al., 2023). However, there has been limited investigation into how seasonal forecasts can inform environmental water management. In this paper we investigate the possibility of developing long-range (i.e., up to 12 months) forecasts of ecological outcomes that could be used to inform annual environmental water planning.

2. METHODS

We develop a framework to produce long-range forecasts of ecological outcomes achievable from environmental water management. The framework links modelling methods to produce forecasts of streamflow, inundation and ecological outcomes, such as waterbird breeding. We implement and evaluate the first two parts of the forecasting framework for two internationally significant wetlands – the Macquarie Marshes and the Barmah-Millewa Forest.

Ensemble forecasts of unregulated inflows in the Macquarie River and upper reaches of the Murray River catchments are generated using the Forecast-Guided Stochastic Scenarios (FoGSS) approach (Bennett et al., 2016). For this study, monthly streamflow forecasts were generated by an initialised GR2M hydrological model (Mouelhi et al., 2006) forced by post-processed climate forecasts from the European Centre for Medium-range Weather Forecasts (ECMWF) seasonal forecasting model (Copernicus Climate Change Service, 2018).

Monthly maps of inundation for the period 1988–2024 were derived from remote sensing observations using the multi-index method (Ticehurst et al., 2022). These maps were used to estimate monthly maximum extent of inundation and floodplain water volume. Statistical models were developed to predict the floodplain water volume from the antecedent floodplain water volume and concurrent total unregulated inflow volumes. Ensemble forecasts of floodplain inundation volume were generated recursively using forecast inflows and the preceding month's floodplain water volume. These floodplain water volume forecasts were then converted to maps of the probability of inundation, firstly converting each ensemble member to a map of inundation extent using a simplified RQ7 model (Teng et al., 2025) and then summarising the ensemble of maps for each pixel and lead time.

The ensemble forecasts of rainfall, runoff and floodplain inundation volumes were evaluated using standard methods assessing skill, bias and reliability.

3. RESULTS AND DISCUSSION

For the two wetlands forecasts of catchment rainfall typically show skill for the first month (indicated by the blue hues in Figure 1), while runoff forecasts can be skilful to lead times of 5-6 months depending on when they are issued (Figure 1). Forecasts of floodplain inundation volume can be as, or more skilful than, forecasts of runoff,

particularly in the Macquarie Marshes, where regulation has a lesser impact on flows that in the Barmah-Millewa Forest. However, the skill of floodplain inundation volume forecasts can be severely impacted by large events that result in rapid changes in inundation and are difficult to predict at long lead times

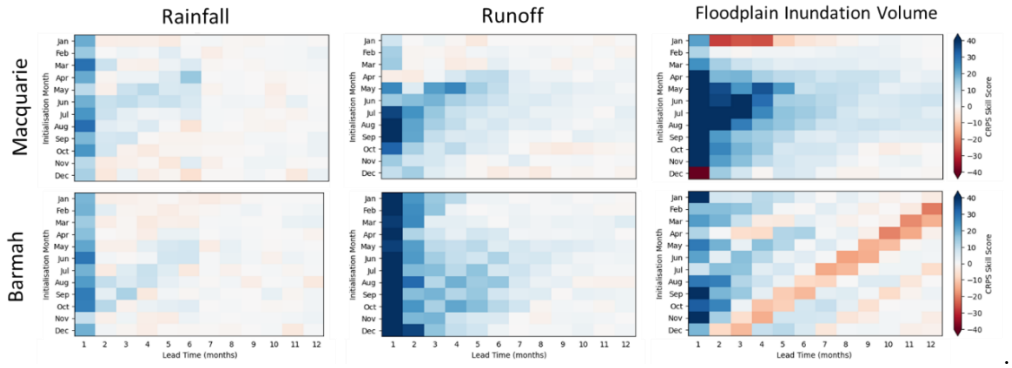

Figure 1 Heat maps of the continuous ranked probability score (CRPS) skill of rainfall, runoff and floodplain inundation volume for the Macquarie Marshes (top row) and Barmah-Millewa Forest (bottom row) catchments

Inundation of riparian wetlands and floodplains is an important outcome of environmental water management. We have shown that it is possible to forecast the likelihood of inundation to lead times that can support annual environmental water planning. Inundation is one critical factor that influences important ecology processes including waterbird breeding, fish spawning and vegetation outcomes. To explore how our inundation forecasting could be extended to consider ecological outcomes, we developed a framework that shows how inundation characteristics provide cues for waterbird breeding and that, with further research, could plausibly be used to translate wetland inundation forecasts to forecasts of waterbird breeding initiation. Nonetheless, a more sophisticated approach that considers factors beyond inundation, including local and remote cues influenced by climate conditions and associated waterbird movements (McGinness et al., 2024), is needed to implement the framework sensibly. Doing so is currently limited by the availability of data needed to establish and verify predictive models and knowledge of the key processes influencing waterbird outcomes. On-going research projects are currently seeking to address these limitations.

ACKNOWLEDGEMENTS

This work was undertaken as a part of the Murray-Darling Basin Water and Environment Research Program (MD-WERP), an Australian Government initiative managed through a partnership between the Murray–Darling Basin Authority (MDBA), Commonwealth Environmental Water Holder (CEWH) and the Department of Climate Change, Energy, the Environment and Water (DCCEEW). We acknowledge the Traditional Owners and their Nations of the Murray−Darling Basin and acknowledge their deep connection to their lands and waters.

REFERENCES

Bennett, J.C., Wang, Q.J., Li, M., Robertson, D.E., Schepen, A., 2016. Reliable long-range ensemble streamflow forecasts: Combining calibrated climate forecasts with a conceptual runoff model and a staged error model. Water Resour Res 52. https://doi.org/10.1002/2016WR019193

Copernicus Climate Change Service, C.D.S., 2018. Seasonal forecast monthly statistics on pressure levels. [WWW Document]. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). https://doi.org/10.24381/cds.0b79e7c5

Matala, A., Hunter, J., Robinson, K., Bennett, J.C., 2023. Building a modern, all-purpose hydrological forecasting system. https://doi.org/10.36334/modsim.2023.matala

McGinness, H.M., Jackson, M. V., Lloyd-Jones, L., Robinson, F., Langston, A., O'Neill, L.G., Rapley, S., Piper, M., Davies, M., Hodgson, J., Martin, J.M., Kingsford, R., Brandis, K., Doerr, V., Mac Nally, R., 2024. Extensive Tracking of Nomadic Waterbird Movements Reveals an Inland Flyway. Ecol Evol 14. https://doi.org/10.1002/ece3.70668

Mouelhi, S., Michel, C., Perrin, C., Andréassian, V., 2006. Stepwise development of a two-parameter monthly water balance model. J Hydrol (Amst) 318. https://doi.org/10.1016/j.jhydrol.2005.06.014

Teng, J., Chiew, F.H.S., Zheng, H., Yang, A., Penton, D.J., Ticehurst, C., Marvanek, S., Vaze, J., Khanam, F., Post, D.A., Pollino, C., 2025. Floodplain inundation in the Murray–Darling Basin under current and future climate conditions. Sci Rep 15. https://doi.org/10.1038/s41598-025-93670-6

Ticehurst, C., Teng, J., Sengupta, A., 2022. Development of a Multi-Index Method Based on Landsat Reflectance Data to Map Open Water in a Complex Environment. Remote Sensing 2022, Vol. 14, Page 1158 14, 1158. https://doi.org/10.3390/RS14051158

