Evaluating the ecological outcomes of environmental watering: the role of the counterfactual

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Abstract: The Australian government's Flow-MER program evaluates the ecological outcomes of Commonwealth environmental water (CEW) in the Murray–Darling Basin using counterfactual models to isolate CEW's contribution to flow regimes and vegetation assemblages, demonstrating CEW's critical role in maintaining river connectivity, inundation of key ecosystems, and preserving vegetation diversity, while ongoing improvements address data limitations for future assessments.

Keywords: *Environmental flows, eco-hydrological modelling, inundation modelling, CEW*

1. INTRODUCTION

The Australian government's Flow-MER program (Cuddy et al. 2024) is a long-term monitoring, evaluation and research program, designed to provide the Commonwealth with the evidence it needs to report (annually) on its obligations under the Water Act and the 2012 (Murray–Darling) Basin Plan to protect, maintain and restore the aquatic ecosystems of the Murray–Darling Basin. The Commonwealth is a major holder of environmental water, which it purchases through licence buy-backs and/or on the open water market. Its Commonwealth Environmental Water Holder (CEWH) division manages this water, and prepares annual watering event plans designed to meet one or more ecological objectives as set out in the Basin Plan. Overarching priorities are to maintain longitudinal connectivity of the rivers of the Basin through to its mouth in South Australia, and lateral connectivity with floodplains and wetlands; and to report annually on the outcomes for the flow regime, vegetation, native fish, species and ecosystem diversity, and food webs and water quality. Importantly from an evaluation perspective, the evaluations are confined to the contribution of Commonwealth environmental water (CEW) only, i.e. not all environmental water. How to quantify this when there is other water in the system (such as natural flows, irrigation deliveries, environmental releases by other water holders, rainfall)?

2. USE OF THE COUNTERFACTUAL IN EVALUATING ECOLOGICAL OUTCOMES – TWO EXAMPLES

The first example is the creation of a hypothetical (counterfactual) daily streamflow time series with no CEW for gauges across the Basin. CEW is known from knowledge of the watering events (start and end dates, volume, flow component) and is removed from the observed streamflow time series (O'Sullivan & Cuddy 2025). To demonstrate its use, **Error! Reference source not found.** shows the flow regime at the Murray River d/s of Yarrawonga Weir gauge. In this figure, the dashed line is the (modelled) mean of the natural flow and the purple shading is the percentiles around the mean. CEW is shown in green. The top horizontal line (indicated by top arrow at bottom left of plot) is the high-fresh threshold at this gauge. As you can see, CEW contributions helped to push flows about this threshold between September and December 2023, and to move flows towards and above the low-fresh threshold (indicated by bottom arrow at bottom left of plot) for much of the remainder of the water year. It also helped to move flows closer to the natural flow regime range (an ecological objective). The CEW contributions in spring were targeted for the inundation of the Barmah-Millewa Forest, an iconic Ramsar site. This was achieved with the contribution of CEW and would not have been achieved otherwise.

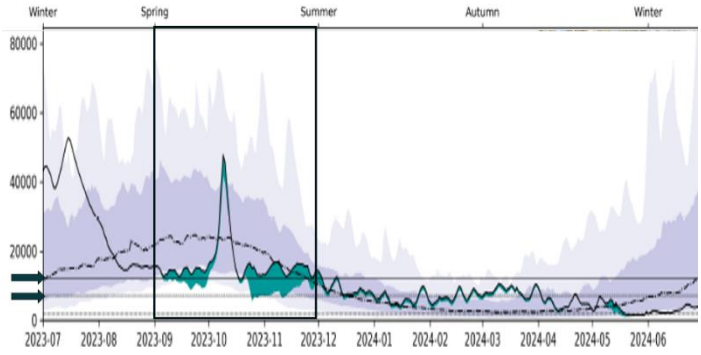
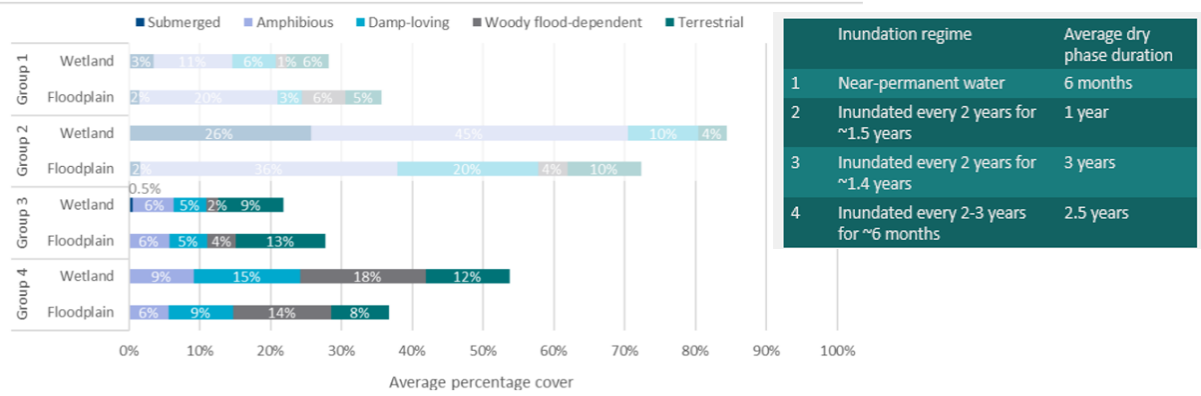


Figure 1 Hydrograph of (modelled) flow at Murray River d/s Yarrawonga Weir for 2023–24 water year (from Sengupta et al. 2025)

The second example of the use of a counterfactual for the evaluation of ecological outcomes of environmental watering is that developed by the vegetation team who looked at associating vegetation assemblages at monitoring sites with different inundation regimes based on observations over the previous 10 years. They developed a counterfactual inundation model to look at what vegetation assemblages might disappear or be disadvantaged should those vegetation assemblages not receive water. In the 2023–24 water year they found that assemblages clustered into 4 groups (see table in Figure 2 for description of the inundation regime and average dry phase duration in each group).



	Inundation regime	Average dry phase duration
1	Near-permanent water	6 months
2	Inundated every 2 years for ~1.5 years	1 year
3	Inundated every 2 years for ~1.4 years	3 years
4	Inundated every 2-3 years for ~6 months	2.5 years

Figure 2 Plot showing the average percentage cover in each group of 5 types of vegetation assemblages: submerged, amphibious, damp-loving, woody flood-dependent and terrestrial (from Dyer et al. 2025)

Without the inundation provided by environmental water, the sites (and their vegetation assemblages) in groups 1 and 2 would receive less water and, by inference, their vegetation assemblages would likely shift to be closer to those in groups 3 and 4. This would likely result in the near-absence of submerged species and substantially less diversity and cover of amphibious and damp-loving species at these locations.

3. NEXT STEPS

The above 2 examples demonstrate how critical the counterfactual is to being able to evaluate the contribution of CEW to meeting ecological objectives. However, the current approaches available to the Flow-MER teams are hampered by lack of observed data, and precision in how environmental water is accounted for, ordered and delivered. As the Flow-MER program enters its new 5-year phase (2025 to 2030), significant investment is being made in advancing the approaches including investigations such as described in Egger et al. (2025) and being presented at this conference (MODSIM2025).

ACKNOWLEDGEMENTS

The Flow-MER Program is funded by the Australian Government through the Commonwealth Environmental Water Holder's Science Program. This paper draws on work conducted by the Flow-MER Basin-scale hydrology and vegetation evaluation teams and the author takes full responsibility for how this work has been interpreted herein – acknowledgement and thanks to Felix Egger, Ashmita Sengupta and Tony Weber for the development of the counterfactual flow time series, and Fiona Dyer, Will Higgisson, Alica Tschierschke, Rui Liu and Tanya Doody for development of the vegetation counterfactual.

REFERENCES

Cuddy SM, Flett DM, Thurgate N and King AJ (2024) Evaluating the Australian government's environmental watering program in the Murray–Darling Basin against legislated objectives. In: Proc. of the International Environmental Modelling and Software Society (iEMSs), iEMSs 2024, 23-27 June 2024, East Lansing, Michigan, USA. pp174–175, https://doi.org/10.5281/zenodo.14285085

Dyer F, Higgisson W, Tschierschke A, Medina M and Doody TM (2025) Basin-scale evaluation of 2023–24 Commonwealth environmental water: Vegetation. Flow-MER Program. Commonwealth Environmental Water Holder, Department of Climate Change, Energy, the Environment and Water, Australia. 2pp.

Egger F, Weber T, Sengupta A and Gibbs M (2025) Are flow thresholds and observed hydrological data enough to evaluate the effect of environmental watering? Abstract, MODSIM2025, Adelaide, Australia.

O'Sullivan J, Cuddy SM (2025) Evaluating the outcomes of environmental watering: Methods. Commonwealth Environmental Water Holder, Department of Climate Change, Energy, the Environment and Water.

Sengupta A, Egger F and Weber T (2025) Basin-scale evaluation of 2023–24 Commonwealth environmental water: Hydrology. Flow-MER Program. Commonwealth Environmental Water Holder, Department of Climate Change, Energy, the Environment and Water, Australia. 2pp.

