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Strategic Environmental Water Use: Optimising Wetland Outcomes with Ecological Feedbacks

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Environmental water management in floodplain wetlands involves complex trade-offs between ecological outcomes and constrained water availability. Water managers rely on Environmental Water Advisory Groups, which bring together stakeholders and researchers to assess real-time ecological conditions and guide adaptive water releases. While this supports responsiveness to short-term ecological change, it limits the evaluation of long-term trade-offs across interacting ecosystem components. This abstract introduces a feedback-driven optimisation framework that integrates real-time ecological state information into environmental water policy design, supporting adaptive and transparent trade-off analysis across multiple ecosystem objectives.

Focusing on the Macquarie Marshes—a Ramsar-listed floodplain wetland in the Murray–Darling Basin—the framework couples ecohydrological simulation with multi-objective policy optimisation. Environmental water release policies are parameterised as conditional rule sets, incorporating ecological triggers such as groundwater thresholds (for River Red Gum health), vegetation condition lags (for non-woody vegetation recovery), and probabilistic bird breeding cues. These ecological models are embedded within an Approximation in Policy Space (APS) structure and evaluated using stochastically generated hydrological sequences with 2,500-year daily timestep resolution, capturing climate variability and regulatory constraints under the current Water Sharing Plan.

High-performance computing (1152-core parallelisation on Gadi) enabled exhaustive exploration of the high-dimensional decision space. This computational efficiency allowed simulation of thousands of candidate policies, each reflecting variations on historical environmental water strategies—such as opportunistic piggybacking, dry-period low flow support, and bird breeding support—and embedding ecological feedbacks (e.g., vegetation condition, groundwater thresholds, bird cues) to dynamically activate or suppress flow rules based on current ecosystem state. The ε-Multi-Objective Genetic Algorithm (ε-MOGA) is used to optimise policy parameters across three competing objectives: maximising waterbird breeding events (Straw-necked Ibis and Intermediate Egret), maintaining non-woody vegetation (NWV) cover, and sustaining forest and woodland River Red Gum (FRRG and WRRG) condition.

The optimisation revealed trade-offs between ecological outcomes. Analysis of Pareto-optimal solutions shows that improving WRRG condition often comes at a cost to bird breeding and NWV cover. Moderate WRRG gains are compatible with strong bird outcomes and minimal NWV loss, but beyond a threshold, further improvements yield diminishing ecological returns. These are accompanied by sharp declines in breeding and NWV, revealing ecological tipping points.

Waterbird breeding metrics were strongly correlated with NWV and FRRG condition, and with strategic optimisation, outcomes exceeding natural conditions were achievable. These results suggest that well-timed, spatially targeted water delivery can enhance connectivity and vegetation structure in ways that significantly boost avian reproductive success. In contrast, WRRG—typically located at higher elevations—requires more extensive flooding, making it especially vulnerable under constrained water availability. Across the solution space, WRRG condition varied widely, while NWV and FRRG showed relatively consistent performance.

Although the framework currently optimises only vegetation health and bird breeding, it demonstrates strong potential to support environmental water managers by extending existing policy structures—systematically parameterising familiar management rules for optimisation. It embeds feedback-driven decisions into a modelling environment that enables exploration of how variations on established rules perform under dynamic ecological conditions. Applied to the Macquarie Marshes, the approach shows how limited water can be deployed more strategically to deliver balanced ecological outcomes, supporting sustainability under climate variability and within existing regulatory constraints.

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