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ANALES

- VOLÚMEN 6 A -

AGUA, AMBIENTE Y SOCIEDAD DEL CONOCIMIENTO

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FUNCTIONAL FLOW REGIMES TO SUPORT RESERVOIR OPERATION AND ECOSYSTEM RECOVERY

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Introduction

Reservoir storage plays an important role in ensuring water and energy security for society, but it also threatens the natural equilibrium of aquatic ecosystems and communities. For many migratory fish species, the recruitment success depends on the flow regime synchronization with the reproductive cycle. In modified downstream flow regimes, a functional simplification of the ichthyofauna diversity is observed, with a marked reduction in migratory and rheophilic species (Oliveira et al., 2018; Santos et al., 2017).

Since restoring natural flow regimes of rivers to their original state is often unfeasible or undesirable, given the various benefits mentioned, the concept of environmental flow emerged to find a balance between the economic uses of water and the preservation of ecosystems (Arthington et al., 2018; Poff et al., 2017).

Choosing an environmental flow, however, brings economic, social and environmental effects to the multiple water users in a basin (Arthington et al., 2018). For example, depending on the seasonality of natural flows and demands, adopting an environmental flow close to the natural regime of a river may reduce reservoir storage, increasing the risk of water or energy deficit during droughts. On the other hand, the adoption of minimum environmental flows may not bring relevant ecosystem responses.

Predicting these effects is a challenge in the water resources management. Restoring an environmental flow regime that triggers an important ecological or geomorphological process in the aquatic ecosystem, also known as functional flows, is a fundamental strategy for drawing up recovery plans and guiding the implementation of environmental flows (Grantham et al., 2020; Yarnell et al., 2015).

As example, for migratory fish species, specific components of a flow regime, such as the magnitude, duration and timing of a flood, are responsible for triggering migration and spawning processes, as well as providing the inundation of the floodplain so that the larvae can develop in refuges against predators and with access to food (Agostinho et al., 2007; Oliveira et al., 2015). Such functional flow regimes were investigated in Dalcin et al. (2022), who modeled the response of aquatic ecosystems to different flow regimes and developed a novel framework to support the negotiation on how to improve reservoir operation practices and mitigate energy tradeoffs. The main aspects of the study are mentioned in the following methodology and results sections.

Methodology

The Paraná River basin was chosen as a case study (figure 1). This basin has significant hydropower development and it suffers the effects of long-term flow regulation (figure 2), with a reduction already widely reported in the literature regarding the abundance of migratory fish (Agostinho et al., 2007; Oliveira et al., 2018).

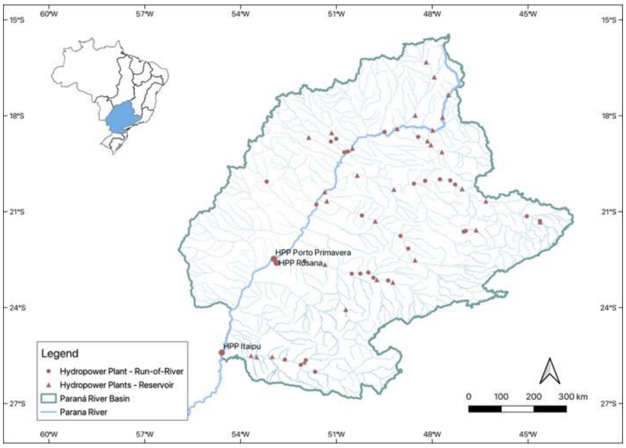

Figure 1. Paraná River Basin.

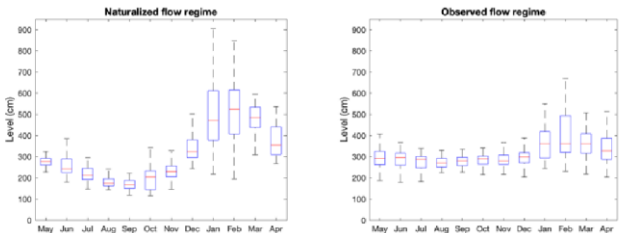

Figure 2. Naturalized and altered flow regime comparison at Porto São José monitoring station. Source: adapted from Dalcin et al. (2022)

The methodology framework consisted of building an artificial neural network model (ANN) to explore different combinations of components of a flow regime (magnitude, duration, time, frequency and variation of flows) and their ecosystem response in terms of migratory fish recruitment.

The ANN model was first trained based on the observed timeseries of daily streamflow/level and fish sampling data. We applied nine metrics (indexes) for flow regime characterization. The flow regime of each year of the time-series was represented by nine metrics (ANN – input variables) and its corresponding annual fish abundance (ANN – output variable) (see Figure 3).

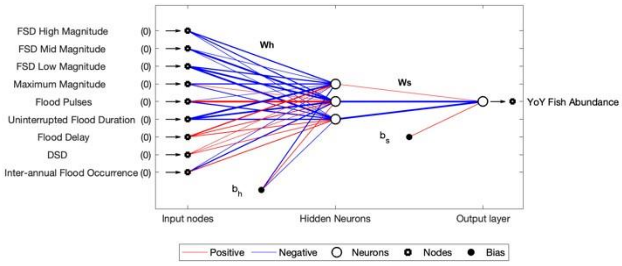

Figure 3. Representation of the ANN model. Source: Dalcin et al. (2022)

We then generated several possible combinations of flow regime components that could be met through reservoir operation (flow regime options) and employed the trained ANN model to predict the resulting annual fish abundances (figure 4). Each flow regime option was derived from a time-series of daily streamflow/level generated based on the naturalized flow regime range provided by Agência Nacional de Águas (ANA) (2020).

As the flow regime option is formed by different combinations of components and it leads to a given functional response of fish reproduction and recruitment (that contributes to the final fish abundance result) it is also termed ***functional flow.***

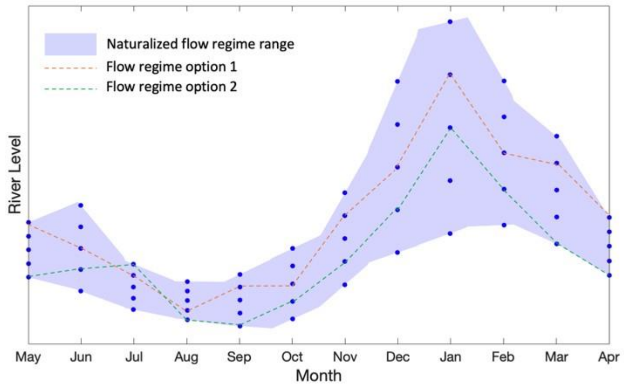

Figure 4.- Generation of flow regime options for recovery. Source: Adapted from Dalcin et al. (2022)

Results

The results quantify different environmental responses to changes in the flow regime, but also to verify those flow regimes that have better performance both for economic uses and for the ecosystem.

Although not always reaching the best response level, relevant YoY fish abundance can still be obtained when combining different flow regime components. Such knowledge is key to provide greater flexibility in negotiating the choice of environmental flow to be implemented in basins that are largely anthropized. Figure 5 compares two functional flow solutions that yield very different results in fish abundance. FH1 restores magnitude with a reasonable duration (at least 2 months), while FH3 has slightly lower magnitude but it cuts back significantly on flood duration. While this may improve reservoir refill to meet other demands later in the year, it significantly impacts fish abundance.

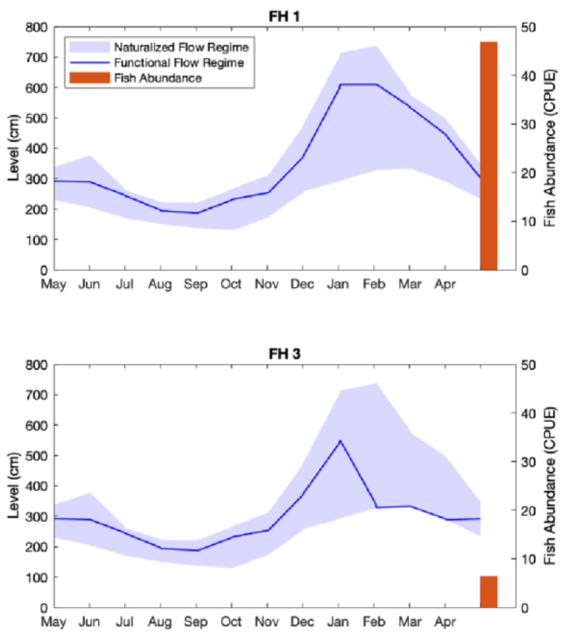

Figure 5. Examples of functional flow regimes obtained. Source: Adapted from Dalcin et al. (2022)

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References

Agência Nacional de Águas (ANA). (2020). SAR - Sistema de acompanhamento de reservatórios. Retrieved from https://www.ana.gov.br/sar/

Agostinho, A. A., Pelicice, F. M., Petry, A. C., Gomes, L. C., & Júlio, H. F. (2007). Fish diversity in the upper Paraná River basin: habitats, fisheries, management and conservation. *Aquatic Ecosystem Health & Management*, *10*(2), 174–186. https://doi.org/10.1080/14634980701341719

Arthington, A. H., Bhaduri, A., Bunn, S. E., Jackson, S. E., Tharme, R. E., Tickner, D., et al. (2018). The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018). *Frontiers in Environmental Science*, *6*. https://doi.org/10.3389/fenvs.2018.00045

Dalcin, A. P., Marques, G. F., Galego de Oliveira, A., & Tilmant, A. (2022). Identifying Functional Flow Regimes and Fish Response for Multiple Reservoir Operating Solutions. *Journal of Water Resources Planning and Management*, *148*(6). https://doi.org/10.1061/(ASCE)WR.1943-5452.0001567

Grantham, T. E., Mount, J., Stein, E. D., & Yarnell, S. . (2020). *Making the Most of Water for the Environment: A Functional Flows Approach for California's Rivers*. San Francisco, CA, United States. Retrieved from https://www.ppic.org/wp-content/uploads/making-themost-of-water-for-the-environment-a-functional-flowsapproach-for-californias-rivers.pdf

Oliveira, A. G., Suzuki, H. I., Gomes, L. C., & Agostinho, A. A. (2015). Interspecific variation in migratory fish recruitment in the Upper Paraná River: effects of the duration and timing of floods. *Environmental Biology of Fishes*, *98*(5), 1327–1337. https://doi.org/10.1007/s10641-014-0361-5

Oliveira, A. G., Baumgartner, M. T., Gomes, L. C., Dias, R. M., & Agostinho, A. A. (2018). Long-term effects of flow regulation by dams simplify fish functional diversity. *Freshwater Biology*, *63*(3), 293–305. https://doi.org/10.1111/fwb.13064

Poff, N. L., Tharme, R. E., & Arthington, A. H. (2017). Evolution of Environmental Flows Assessment Science, Principles, and Methodologies. In *Water for the Environment* (pp. 203–236). Elsevier. https://doi.org/10.1016/B978-0-12-803907-6.00011-5

Santos, N. C. L. dos, de Santana, H. S., Ortega, J. C. G., Dias, R. M., Stegmann, L. F., da Silva Araújo, I. M., et al. (2017). Environmental filters predict the trait composition of fish communities in reservoir cascades. *Hydrobiologia*, *802*(1), 245–253. https://doi.org/10.1007/s10750-017-3274-4

Yarnell, S. M., Petts, G. E., Schmidt, J. C., Whipple, A. A., Beller, E. E., Dahm, C. N., et al. (2015). Functional Flows in Modified Riverscapes: Hydrographs, Habitats and Opportunities. *BioScience*,*65*(10),963–972. https://doi.org/10.1093/biosci/biv102