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On modeling the interdependency among adaptive reservoir operation, floodplain land-use, and agricultural production: a socio-hydrological approach.

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Summary

- Human decisions during or after a disaster may not be rational, but there can be patterns in such errors according to their cognitive biases.
- Our study can provide a novel framework for reservoir operation with a socio-hydrological approach involving cognitive biases and adaptive human behaviors.
- Reservoir operators' decisions may be more affected by the most frequent and recent events in the past.

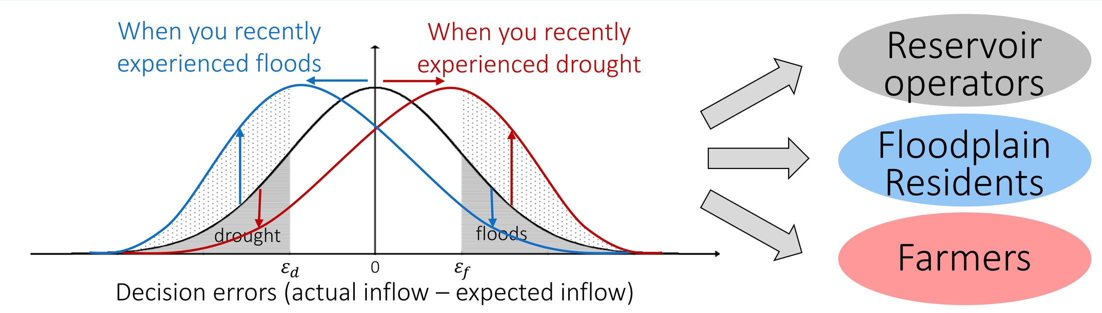


Figure 1. Conceptual diagram of the effect of cognitive bias on different stakeholders

1. Introduction

Research gap

- Conventional reservoir operation models assume normative/ideal operation
  - Economic perspectives: Maximizing utility (i.e., hedging rules)
  - Normal probability distribution for inflow errors (Wallington & Cai, 2020)
- Growing demand for considering **human behaviors** in adaptive reservoir operation
  - **Recurring patterns of errors** in the operator's decision-making (Fig. 1)
  - Interaction with society (i.e., floodplain encroachment, irrigation water demand)

Observed patterns: Cognitive biases and Adaptive behaviors

- Under limited time and information, stakeholders' decision may be biased by their past experiences and memory (Tversky & Kahneman, 1973).

Somerset Dam (1950s)

Wivenhoe Dam (1970s)

- No major floods for 30+ years
- Human encroachment on floodplain
- Prolonged drought for 15+ years

Brisbane floods (2011)

Figure 2. Reservoir operators under-weighted the risk of extreme flooding in Brisbane, 2011

Study area

- Lake Mendocino (Coyote Valley Dam) is a multi-purpose water reservoir on the East Fork of the Russian River, CA
- Residents are more vulnerable to flooding
  - Having a higher priority of water rights rather than farmers
- Farmers are more vulnerable to drought
  - Flood seasons are winter and early spring, less impact on agricultural products
  - Wine grapes (most of the agricultural land) are a well-known flood-resistant crop

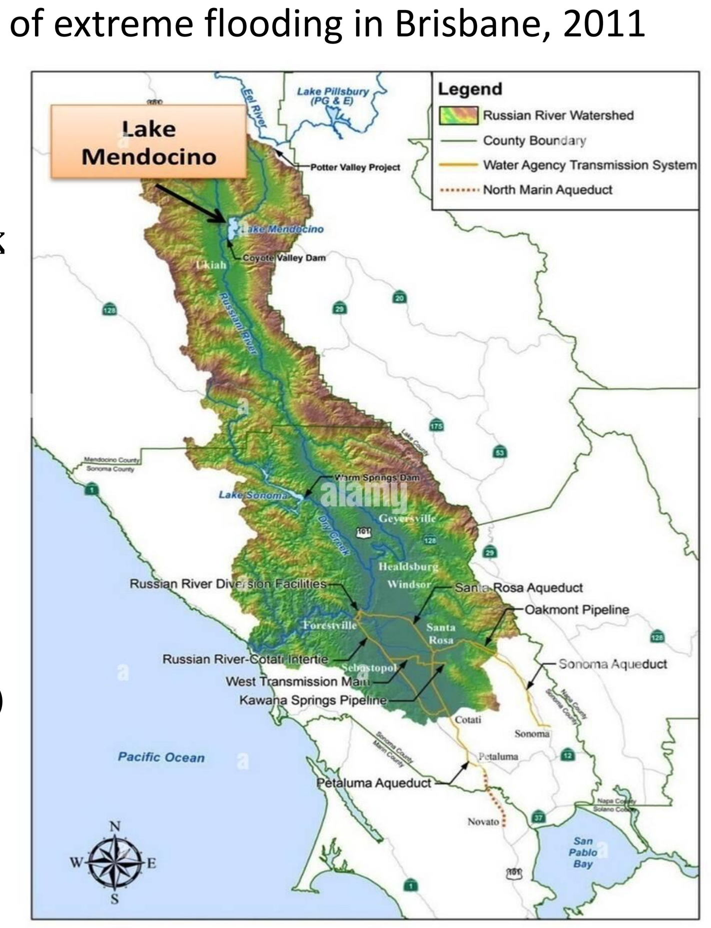


Figure 3. Map of the study area

2. Research question

- What is the effect of interplay between **operator's bias** and **downstream communities's adaptive behaviors** on system-level outcomes?

3. Novel reservoir operation modeling framework

- We propose a novel framework for reservoir operation with a socio-hydrological approach involving cognitive biases and adaptive human behaviors.

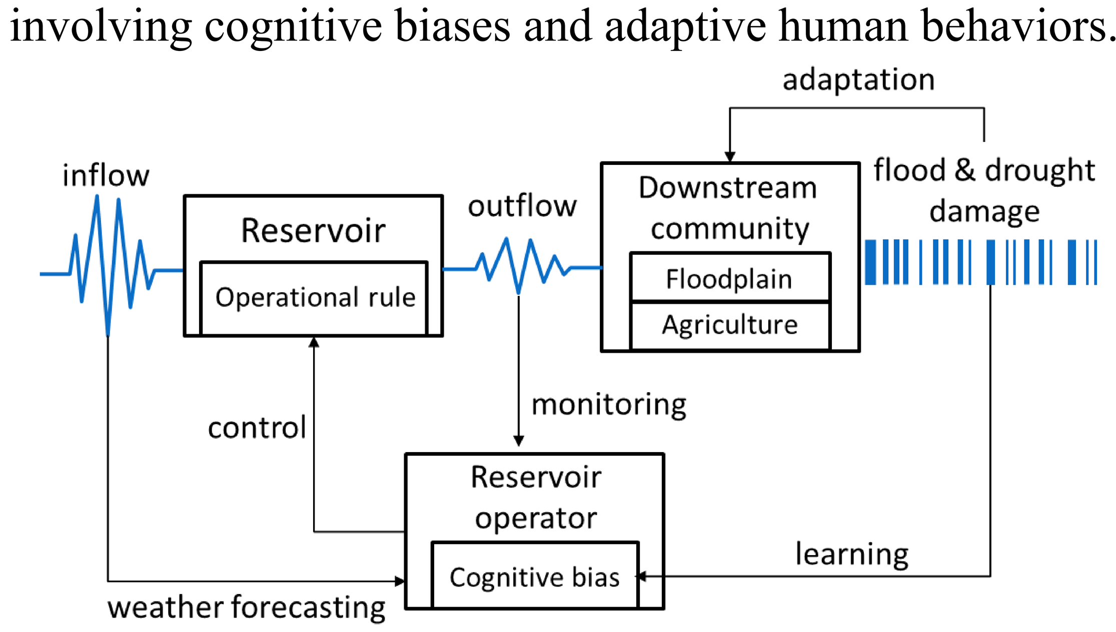


Figure 4. Model structure

- Our case-driven stylized reservoir operation model to control the discharge rate using a proportional–integral–derivative (PID) controller.
  - PID controller: Using output feedback as a part of control
  - F controller: Using the expected external disturbances as a part of control

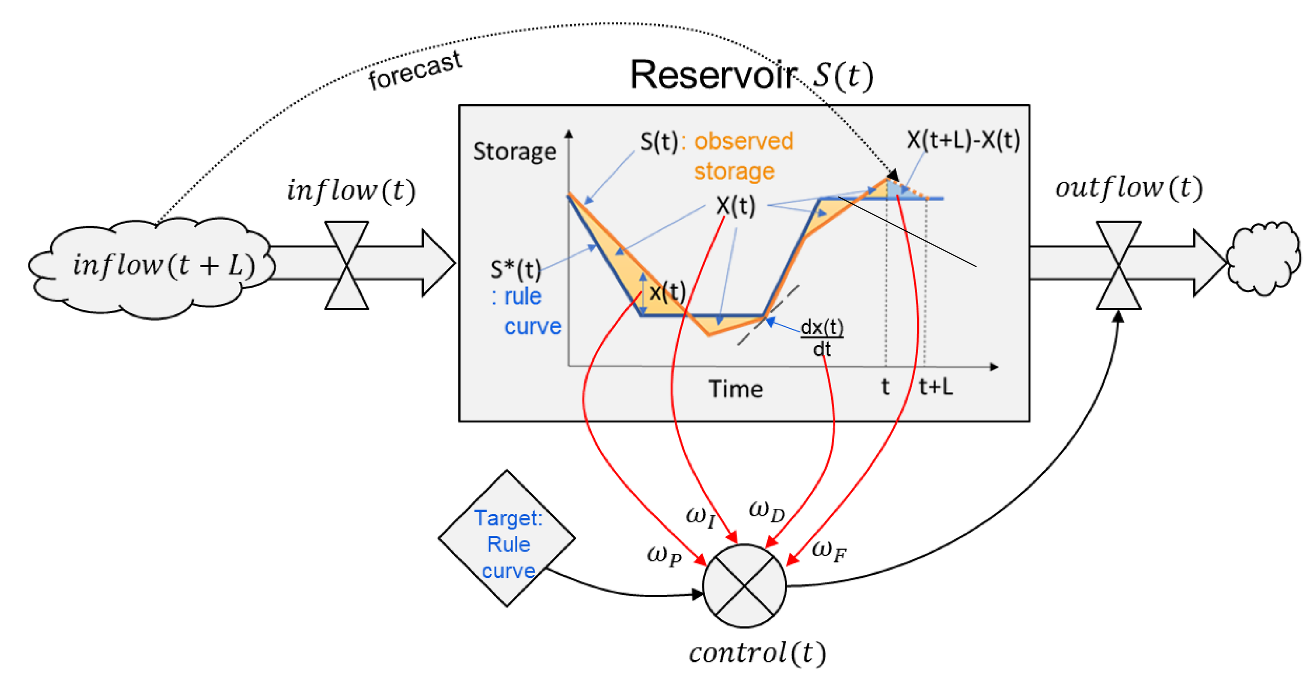
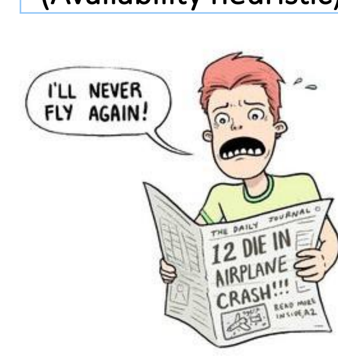


Figure 5. Different controllers (P,I,D, and F) between the observed storage and the operational rule

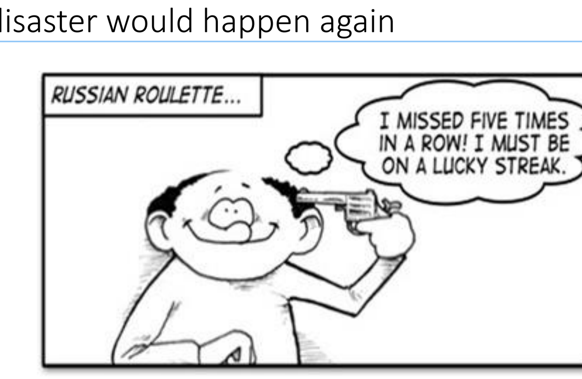
- Due to limited access to actual reservoir operational data, we conducted scenario analysis of cognitive biases to assess how different types of past disaster memory might influence the decision-making of a reservoir operator (Table 1).

Table1. Scenarios of reservoir operator's biases (Gigerenzer & Gaissmaier, 2011)

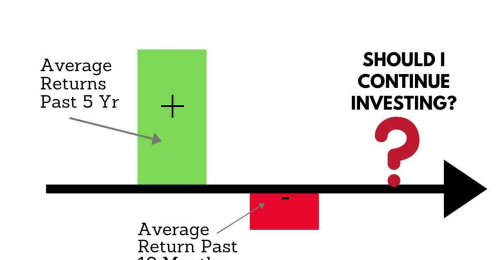
Cognitive Bias	Assumption of Operator's behavior	PID controller
Perfect rationality (No bias)	The operator does not care about past disasters and strictly follows the operation rule	P and D
Salience bias	The operator believes that the most severe disaster in the past would happen again	P, D, and I (accumulated damages of severe disasters in the past)
Frequency illusion (Gambler's fallacy)	The operator believes that the most frequent disaster in the past would happen again	P, D, and I (accumulated damages of frequent disasters in the past)
Recency bias (Availability heuristic)	The operator believes that the most recent disaster would happen again	P, D, and I (accumulated damages of recent disasters in the past)



Salience bias



Frequency illusion

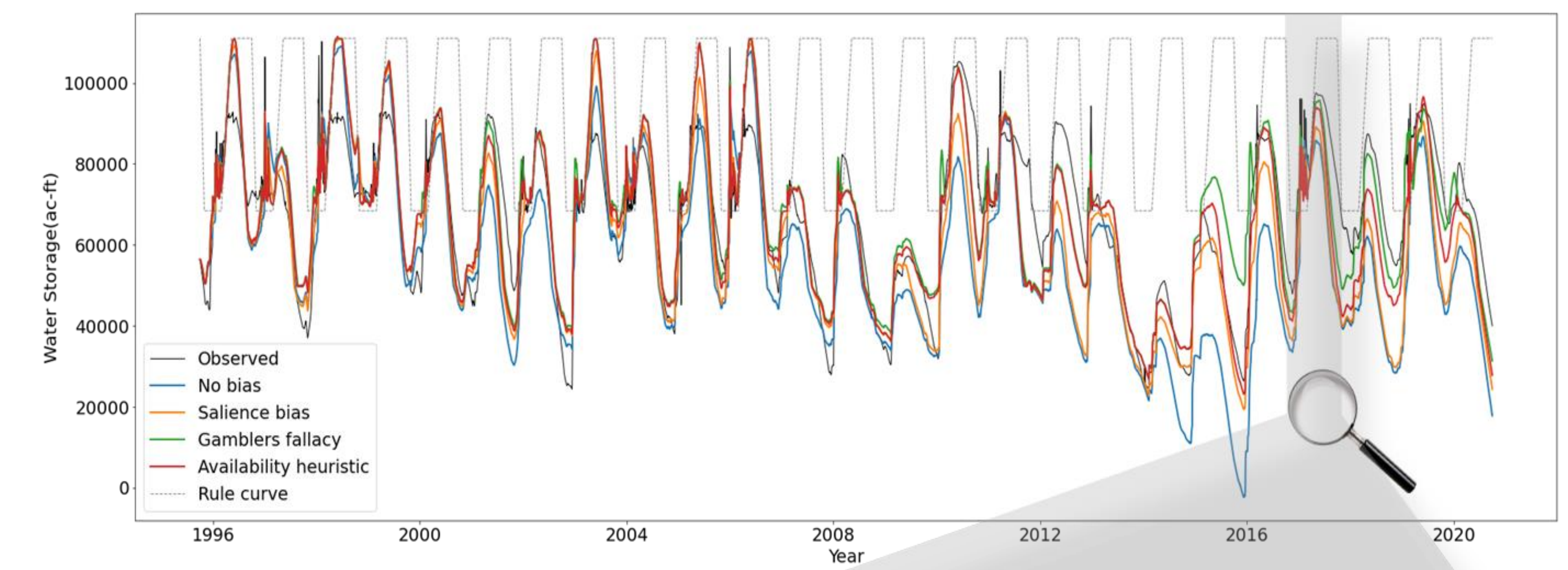


Recency bias

Source: https://medium.com/make-better-decisions/unhappiness-and-availability-heuristic-657060d3655a; https://tceti.nz/gamblers-fallacy/; https://ontrustcap.com/avoid-the-trap-of-recency-bias/

4. Results and Discussion

- We are not aiming to prove the existence of the operator's biases, but to explore which types of scenarios can provide a better understanding of observed patterns.
- The operator was likely affected by **the most frequent and recent events in the past**. Actual reservoir operation can be affected by the combination of different types of cognitive biases.



Scenario	Goodness of fit (R^2)
No bias	0.222
Salience bias	0.535
Frequency illusion	0.734
Recency bias	0.730

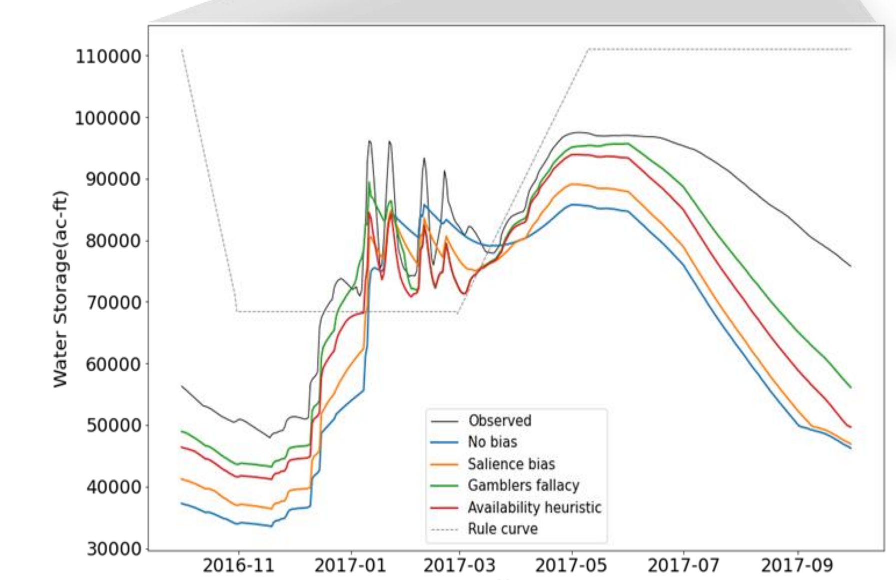


Figure 6. Simulation results of water storage levels according to different types of reservoir operator's biases of Lake Mendocino, CA (1995~2020) and goodness-of-fit of each scenario (Garcia et al., under review)

5. Conclusion

- Our study propose a novel framework for reservoir operation with a socio-hydrological approach involving cognitive biases and adaptive human behaviors.
- Our results can provide a guideline for reservoir operators to minimize unnecessary damages caused by their memory bias according to different types of disasters.
- Beyond demonstrating the effect of human memory bias on reservoir operation, our study suggests the importance of updating operational rules adaptively.

Acknowledgement

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