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Evaluating Mismatches between Legislation and Practice in Maintaining Environmental Flows

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Abstract: Freshwater is essential to human communities and stream ecosystems, and governments strive to manage water to meet the needs of both people and ecosystems. Balancing competing water demands is challenging, as freshwater resources are limited and their availability varies through time and space. One approach to maintain this balance is to legally mandate that a specified amount of stream flow be maintained for stream ecosystems, known as an environmental flow. But laws and regulations do not necessarily reflect what happens in practice, potentially to the detriment of communities and natural systems. Through a case study of Puerto Rico, we investigated whether water management in practice matches legislative mandates and explored potential mismatch drivers. We focused on two governance targets—equitable allocation and water use efficiency—and assessed whether they are enshrined in the law (*de jure*) and how they manifest in practice (*de facto*). We also explored agency accountability through identifying agency structure and whether consequences are enforced for failing to carry out responsibilities. Our results indicate there are mismatches between how freshwater is governed by law and what occurs in practice. This study suggests that agency accountability may be necessary to consider when developing environmental flow legislation that will effectively achieve ecological outcomes.

Keywords: environmental flows; accountability; *de jure*; *de facto*; Puerto Rico

1. Introduction

Water management via dams and withdrawals reduces river flow and creates cascading effects such as altered ecological function, decreased biodiversity, and loss of ecosystem services [1,2]. Over 750 scientists from 50 countries have articulated the need to maintain river flows for environmental protection in the Brisbane Declaration, which defines environmental flows as “the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems” [3]. However, crafting environmental flow policies has proven to be difficult. Significant ecological complexity, including multiple ecological goals, a variety of methods to assess outcomes, significant hydrologic variability across river systems, and multiple dimensions of hydrologic processes, hampers the ability to prescribe environmental flows [2,4,5].

In parallel with ecological complexity, social and political impediments also interfere with legislation development, such as the misallocation of power and responsibilities within agencies [6], financial limitations [7], and regulations lacking sufficient enforcement mechanisms [8]. Additionally, as demonstrated by a growing body of literature addressing environmental flow governance issues e.g., [9,10], legislation implementation remains challenging. Even when flow protection policies are

legally in place, there is often little evidence of enforcement (see Baer and Ingle (2016) for an example from the southeastern U.S.) [11]. This misalignment between governance targets enshrined in the law (a *de jure* perspective) and whether and how they manifest in practice (a *de facto* perspective) is a recognized factor affecting governance outcomes [12,13].

Governance research has revealed that environmental management in practice often departs from formal governance systems established by law [14], and more complex legislation is generally less tractable to those responsible for implementation [15]. However, in water management systems, regulation implementation can be impeded by a lack of necessary components outlined in the law, leaving major implementation decisions up to individual agencies [16]. To evaluate differences between legislation and practice in developing water governance regulations, a two-pronged *de jure* and *de facto* approach has been used to highlight mismatches between who participates and influences water governance formation [17].

In this paper, we explored mismatches in *de jure* and *de facto* water governance to better understand how environmental flows are managed in Puerto Rico, where high water variability resulting from annual dry seasons and periodic drought conditions limits the amount of available freshwater to meet human and ecological needs. We focus on two water governance targets that represent potential mechanisms to facilitate environmental flow legislation enforcement: equitable allocation and water use efficiency. We also explored the accountability of water management agencies at the state level and whether agency accountability influences environmental flow legislation implementation. We focus on identifying accountability as it helps to establish a network of influence within a governance system [18] and determines actors' motivations. Our findings contribute to the ongoing conversation of identifying factors that need to be addressed to move towards effective environmental flow governance [9].

Accountability

According to Bäckstrand (2008) accountability means "liable to be called into account; responsibility" [19]. Based on this requirement, at least two actors are needed for accountability to exist: one actor demonstrates they have met their responsibilities, and a separate actor enforces consequences if responsibilities are not met [19,20]. Many accountability types exist and are distinguished by "to whom" an actor gives account [21,22]. For example, political accountability refers to party allegiance or adherence to party expectations [22], whereas legal accountability is "based on specific responsibilities, formally or legally conferred upon authorities" [21].

Accountability is a useful lens for evaluating environmental flows as it illustrates which actors have influence over particular standards or expectations, such as environmental outcomes [6], highlights the relationship between actors, and ultimately increases our knowledge of how actors function within a governance system [23]. Though multiple mechanisms for identifying accountability exist [21,23], we identified agency accountability through the existence of consequences for not following through with responsibilities [22].

2. The Complexity of Water Management in Puerto Rico

Our examination of environmental flow governance is focused on Puerto Rico, a tropical island that is a U.S. territory. Surface water is the main source of freshwater for the island population of nearly 3.2 million [24]. Ecologists have identified the importance of leaving a minimal flow at dams and intakes to facilitate migratory shrimp movement from the ocean to the rivers [25].

2.1. Water Management Agencies

Freshwater in Puerto Rico is managed similarly to U.S. states: federal agencies oversee water quality and navigation, and water quantity decisions are made by state agencies. Three state agencies are involved with managing water quantity in Puerto Rico: Departamento de Recursos Naturales y Ambientales (DRNA), Autoridad de Energía Eléctrica (AEE), and Autoridad de Acueductos y

Alcantarillados (AAA). DRNA was created by the Commonwealth for managing, protecting, and sustainably developing the “natural, environmental and energy resources of the Island” [26] (§ 2) and is led by a Governor-appointed Secretary [26] (§ 1). DRNA is responsible for creating the Water Plan, which is updated periodically and outlines how each water body is used along with water conservation and management goals.

The public energy corporation, AEE, legally controls the distribution of water within the hydropower reservoirs [27] (§ 196a) and is managed by a board of directors appointed by the Governor. Finally, AAA is the public water corporation created by the Commonwealth government and is responsible for setting and charging fees to finance the water and sewage services it provides to citizens [27] (§ 144). AAA can make water conservation regulations regarding domestic use and is charged with ensuring a consistently available water supply for its consumers [27] (§ 159). AAA is managed by nine board of directors members, five of which are selected by the Governor and confirmed by the Senate [27] (§ 143). Though AAA has water resource regulatory responsibilities assigned by state law, it is also part of the regulated water user community. For example, AAA waste discharge must adhere to Clean Water Act federal standards and state regulations.

Federal agency jurisdiction extends to management issues related to barriers within navigable waters, federally listed endangered species, and water quality. If an instream barrier is to be placed in a navigable river, permission must be obtained from the U.S. Army Corps of Engineers (USACE) and authorized by the Secretary of the Army [28] (§ 403). As per the Endangered Species Act (1972), the U.S. Secretary of the Interior coordinates interagency efforts to protect endangered species and their habitat [29] (§ 1533). The US Fish and Wildlife Service (USFWS) must also be consulted if the waters contain a federally listed endangered species [29] (§ 662).

Within the El Yunque National Forest (EYNF) boundaries, the US Forest Service (USFS) has authority to grant access to freshwater resources. Though waters within national forest boundaries are available for domestic purposes [29] (§ 481), the U.S. Secretary of Agriculture must review plans for the intended water use prior to granting a right-of-way [30] (§ 1761). In terms of water quality, the U.S. Environmental Protection Agency (EPA) is tasked with developing and enforcing water quality standards and issuing wastewater effluent permits under the Clean Water Act [28] (§ 1251d). The EPA also assists the USACE in issuing wetland disturbance permits [28] (§ 1344) and delegates the in-state implementation of water quality regulations to a state-level agency. In Puerto Rico, this agency is the Junta de Calidad Ambiental (JCA), and its board is appointed by the Governor [31] (§ 8002a).

2.2. The Ecology of Puerto Rican Streams

More than 30 years of EYNF stream studies have highlighted the ecological importance of maintaining some streamflow to support ecosystem function [32]. Evidence suggests a trickle of water can be enough to allow for some migratory aquatic organisms to complete their life cycle (J. Benstead, J. March, P. Torres personal observation), underscoring the disproportionately large effect that maintaining streamflow can have on the ecosystem. A regulation mandating that the minimum flow of the Q99 be maintained in certain circumstances has been in place since 2008 [24]. The Q99 is the flow exceeded in a river 99% of the time. The importance of environmental flows ecologically, as well as the existence of a minimum flow regulation, provide a strong basis for examining environmental flow governance in Puerto Rico.

We used the minimum flow requirement as a proxy for environmental flows throughout our analysis. Although it has long been recognized that maintaining flow magnitude is not sufficiently comprehensive to ensure stream function [4], the environmental flow legislation in many states only protects minimum flows [11]. Additionally, a minimum flow in Puerto Rico’s stream systems is ecologically significant in terms of maintaining aquatic fauna. Aquatic migratory species rely on flowing water to move up and downstream to complete their life history [25], and these animals underpin many crucial stream ecosystem functions [33,34].

3. Materials and Methods

We developed a framework to evaluate de jure and de facto environmental flow governance relative to two targets: equitable allocation and water use efficiency (Figure 1). Although other definitions exist, we define equitable allocation as the principle that every water user has the right to a reasonable amount of water proportional to its needs [35]. Though applied to water shared across political boundaries, here we examine equitable allocation across different users or sectors (i.e., domestic, industry, agriculture, and the environment). We consider water use efficiency as “the accomplishment of a function, task, process, or result with the minimal amount of water feasible” [36]. A legal platform ensuring users have water access (equitable allocation) and minimizing water waste (water use efficiency) can contribute to maintaining aquatic ecosystems [36]. When equitable allocation and water use efficiency exist by law and in practice, environmental flows are therefore more likely to be achieved (Figure 1).

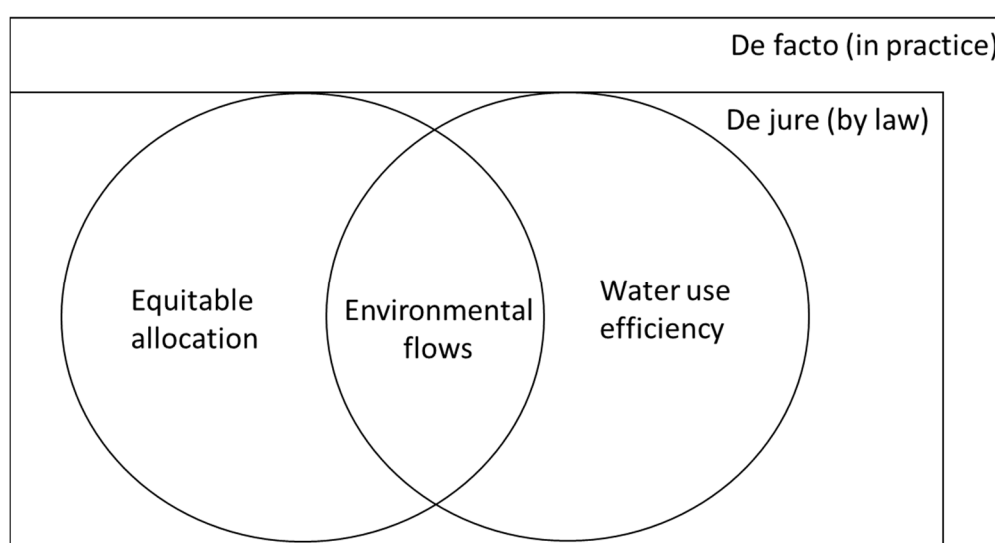


Figure 1. The method we used to evaluate mismatches in environmental flow governance in Puerto Rico. We identified two targets (equitable allocation and water use efficiency) in legislation and in practice.

We identified each water target in legislation (de jure) and in practice (de facto) using the criteria outlined in Table 1. We located statutes and regulations through Westlaw [37], using the following search terms: Puerto Rico, water, allocation, efficiency, water use, environmental flow, and minimum flow. To pinpoint the water targets in practice, we conducted interviews with key informants from federal and state agencies involved in Puerto Rican water management, specifically: DRNA, AAA, AEE, JCA, Departamento de Agricultura (DA), USFS, ACE, and USFWS. We conducted semi-structured interviews in Puerto Rico from March to August 2016, with a list of approximately 10 pre-determined questions for each interviewee. The questions were focused on determining whether the two water targets are achieved in practice. The final sample consisted of ten individuals who worked or provided consulting services for state agencies, and five individuals who worked or consulted for federal agencies. The study was conducted in accordance with the Institutional Review Board (IRB), and the protocol was approved by the IRB of the University of Georgia (IRB code: STUDY00002258). All subjects gave their informed consent for inclusion before they participated in the study.

Once we located all relevant legislation and transcribed all interviews, we used the indicators in Table 1 to identify equitable allocation and water use efficiency. If we found evidence to support the indicators, we determined that the water target did exist. Several indicators in Table 1 allowed us to identify accountability, especially those that focus on consequences or court cases, as accountability exists when there are consequences for not following through with responsibilities. Our analysis is

focused on the accountability of state agencies involved with environmental flow management, as environmental flow is managed at the state level.

Table 1. Indicators used to determine whether two water governance targets, equitable allocation and water use efficiency, exist in legislation (de jure) and practice (de facto).

	de jure Indicators	de facto Indicators
Equitable allocation	#1: Water users or uses are clearly defined in the legislation	
	#2: Statutes or regulations exist outlining how water gets apportioned among these uses and users	#5: Water is permitted in practice
	#3: Court cases uphold the principles in #2 providing clarity on how decisions on allocation are made	#6: Water allocation under drought conditions ensures all users have water access
	#4: Water permitting conditions established in implemented regulations ensure the principles in #2 are upheld	#7: Priority water uses or users do not exist
Water use efficiency	#8: The legislation mandates waste minimization by relevant agencies and users	
	#9: Consequences for violations of #8 are clearly specified	#12: Examples of water waste as outlined by the legislation
	#10: Water management agencies are subject to legal recourse	#13: Agencies enforce consequences for water waste
	#11: Evidence of court cases providing clarity on efficiency	

4. Results

4.1. Equitable Allocation: De jure

Puerto Rican legislation states “the waters and bodies of water of Puerto Rico are the property and wealth of the People of Puerto Rico. The Commonwealth Government shall administer and protect this patrimony in the name and on behalf of the Puerto Rican people” [31] (§ 1115a). The Water Law assigns DRNA the responsibility for creating a Water Plan, which determines the island’s freshwater use for multiple users. These users include “the natural, social and economic systems which depend on the resource for their subsistence and development” [31] (§ 1115a) (Table 1#1). The Commonwealth is committed “to achieve the most equitable and fairest distribution of its waters” [31] (§ 1115a); however, the only user allocated a specified water amount is the environment (Table 1#2). The Water Plan specifies the Q99 be maintained downstream of new intakes (Plan de Agua 2008). There are no existing court cases that clarify how equitable allocation decisions are made in Puerto Rico (Table 1#3).

DRNA issues water withdrawal permits [31] (§ 1115d). Withdrawal permits are issued for up to ten years at a time, and the agency sets the permitting fee based on water volume [31] (§ 1115h). When a water user submits a permit request, the application must include evidence demonstrating that there is substantial streamflow to support the withdrawal amount at the proposed site. DRNA must take into consideration the impact of the proposed water withdrawal on multiple entities, such as the economy and the environment (Table 1#4). Domestic or agricultural users applying for small withdrawal permits may be exempt from the application process and the associated fee, as these water uses are prioritized [31] (§ 1115n).

4.2. Equitable Allocation: De facto

The interviewees indicated three areas where practice did not meet legislation. The first is poorly informed instream flow management, resulting from DRNA's unkempt permitting system. Intake information is not well tracked by the agency, including intake location, number of intakes per watershed, and water withdrawal amount. This makes it difficult for DRNA to accurately assess whether an additional intake installed on a river with multiple existing withdrawal permits will decrease stream flow below the minimum threshold (Table 1#5). Though DRNA is the agency that approves withdrawal permits, the permit application is reviewed by multiple entities, including federal agencies (federal employee, July 2016). For example, the USFS becomes involved if a proposed intake is located on, or will affect, national forest land. In the early 1990s, a new intake was proposed for Rio Mameyes, a barrier-free river originating from EYNF. AAA submitted a proposal to install a water intake paired with a dam to remove 15 million gallons per day (MGD). One interviewee walked us through USFS's response to this proposal.

"We said ... first of all, you don't have 15 (MGD), and we realized that the most that river could give in a safe way would be 5 MGD ... And we said 'You are going to dry the river by your proposal.' And we're very cognizant of not drying the river and keeping always a base flow. So that's why we came up with [the] solution ... put a limit on it to 5 MGD so that it will always maintain flow, it will never go dry. But in that case, what we did as an agency was to use the research ... to defend our responsibility over the organisms that live inside the forest [but] depended on the [river] outside for their survival" (federal employee, June 2016).

This example reveals issues with DRNA's permitting process, as USFS was the agency that found that this withdrawal would be ecologically unsustainable.

Another mismatch is ineffective enforcement of environmental flows during drought (Table 1#6). In 2015, during one of the most severe droughts in Puerto Rico over the last 100 years, concerned citizens notified DRNA that Rio Blanco, a river flowing from EYNF to the ocean, was dry. Rio Blanco contains a dam with a V-notch weir, intended to create a AAA instream reservoir and maintain a minimum flow. However, AAA employees had deliberately obstructed the weir to fill the reservoir, as the drought-reduced stream flow was not sufficient. This was in violation of AAA's water withdrawal permit (issued by DRNA), which requires a 2.26 MGD minimum flow [38]. DRNA forced AAA to remove the obstruction, as low flows can stress the downstream ecosystem [38]. Though this situation represents an example of DRNA enforcing consequences, consistently maintaining minimum flows across the island appears challenging. Another river originating from EYNF, Espiritu Santo, had more water permitted for withdrawal than was available on at least 30 days from 2005 to 2013 [39] with no evidence of minimum flow enforcement.

A final mismatch is the failure to ensure each water user receives an amount proportional to their needs. In southeastern Puerto Rico, there are multiple reservoirs operated by AEE that were established in the early 1900s to support agriculture and hydropower. However, reservoir maintenance represents a significant financial loss to AEE, as it costs USD 300 per acre foot to maintain the system and farmers pay USD 2 per acre foot (state government employee, July 2016). As the farming industry declined in the 1970s, AEE began to sell the excess water to AAA to recuperate their financial investment (state government employee, July 2016). In 2012, the DA requested more water to increase crop production and the island's food security, but DRNA informed the DA there was no water available (Table 1#7). In this case, DRNA does not seem to prioritize equitable allocation of Puerto Rico's waters to allow all users a reasonable amount to meet their needs, even when the water previously belonged to the user asking for more water.

Although DRNA may enforce the minimum flow regulation in extreme cases (i.e., when the stream is dry), we did not find evidence that DRNA is held accountable for this responsibility (i.e., there are no agency consequences when Rio Espiritu Santo is overdrawn) or for achieving equitable water allocation across users.

4.3. Water Use Efficiency: De jure

The Commonwealth must ensure the island's water bodies are used in the public's interest "and with their best, most beneficial and most reasonable use . . . to protect our people from the adversities of the shortage, misuse, waste and pollution of such an essential resource" [31] (§ 1115a) (Table 1#8). Though DRNA, AAA, and AEE are all tasked with conserving water through legislation, DRNA is the agency legally responsible for creating criteria to evaluate the most beneficial and reasonable water use and defining water "waste" [31] (§ 1115d). However, what constitutes water waste is unclear, as the Water Plan only states water should be used reasonably and in the public's best interest. Additionally, violations for water wasters are not clearly stated in legislation or in the Water Plan (Table 1#9). In terms of residential water users, AAA is granted the authority to enforce rules to maintain its operations [27] (§ 144), indicating that the agency can impose water use restrictions (or rationing) on AAA customers.

AAA's autonomy from the government, especially regarding financial obligations [27] (§ 144), has been legally affirmed [40]. Though AAA argued "the Commonwealth's significant financial support of (AAA)'s activities" indicates the agency is part of the Commonwealth, suggesting it cannot be sued, Puerto Rico's own Supreme Court has "consistently concluded that (AAA) is not an alter ego of the central government" [40]. This indicates that public corporations, such as AAA and AEE, can be sued (Table 1#10). In fact, AAA was sued by the EPA and JCA because AAA wastewater treatment facilities were not in compliance with environmental standards set by the Clean Water Act (1977) [41]. However, although AAA can be sued in court, we did not find any court case examples related to efficiency (Table 1#11).

4.4. Water Use Efficiency: De facto

It seems there are no clear examples of agencies wasting water (Table 1#12) based on the interviews. Though it can be difficult to pin-point an example of water waste, as it is not clearly defined, droughts force water managers to conserve the resource by identifying perceived wasted water. In May 2015, AAA enforced water rationing for 1.5 million domestic users in the island's north-central and northeastern regions. Residents were fined USD 250 for using potable water to wash patios, roofs, or cars, as this was considered wasteful [42]. Additionally, AAA limited the amount of time domestic users had running water by turning the water delivery system off.

Although turning the delivery system off was intended to conserve water, inconsistent pipe pressure wasted water by exacerbating existing leaks and creating new ruptures. Multiple leaks were reported throughout the metropolitan water delivery zone during water rationing, and one resulted in the "loss of millions of gallons of potable water" [43]. Although water loss perpetuated by AAA actions possibly intensified or prolonged water rationing for domestic users, water delivery pipe leaks were not formally identified as waste. Additionally, no consequences were enforced for the pipe leaks, despite multiple regulatory agencies having legal responsibility for water conservation. Thus, it does not appear that state agencies experience consequences for wasting water in practice (Table 1#13). We consider this inconsistent enforcement of water use efficiency standards as a mismatch between water use efficiency legislation and what occurs in practice.

AAA seems to be the main agency responsible for water use efficiency in practice (state government employee, July 2016), representing a mismatch in terms of regulatory responsibility. However, though there are financial consequences for AAA if water use efficiency is not maintained, as leaks represent a financial cost for the agency (former AAA employee, July 2016), there do not seem to be legal consequences. Though AAA was only able to respond to 25% of 450 daily calls reporting leaky pipes [44] and lost 60% of its treated water during a drought, the agency has experienced no legal consequences. However, AAA was held accountable for its water quality responsibilities by the EPA and was forced to pay a fine for violating federal regulations [45]. One reason why AAA is held accountable for water quality regulations, and not water quantity, seems to be the structure of state agencies. State agencies are subject to political accountability, which likely interferes with their attempts to enforce consequences when regulations are not followed by other state agencies.

In this case, political accountability is owed to the Governor, as this person can enforce consequences if responsibilities are not met. This opportunity is created from the gubernatorial appointment of state agency leadership. All state-level water management agencies are directed or overseen by individuals appointed by the Governor. Agencies seem to be expected to fulfill the Governor's desires, and consequences exist if this does not occur, indicating political accountability. One interviewee stated:

"... the first Secretary [DRNA] had in 1976. He disobeyed, or did not comply with, a requirement of the office of the Governor. So, he got... a letter for his resignation. No choice. Sign or we fire you. So, he was fired. The head of (AAA)... he was fired... by the Governor" (AAA consultant, May 2016).

The Governor's influence is highlighted by exploring how domestic user water rates are set in practice. Although AAA is legally able to independently set water rates, the agency must have the Governor's support to charge more for water in practice (former AAA employee, July 2016). This is because citizens perceive the water rate is the Governor's responsibility, as AAA is managed by individuals appointed by the Governor. An increase in water rates thus triggers a decline in the Governor's public approval and the potential loss of a re-election. Due to the existence of consequences for going against the Governor, AAA does not increase water rates at the level necessary to finance its operations (former AAA employee, July 2016).

Political accountability to the Governor for all state agencies also shapes interagency relations. For example, we did not observe state agencies holding AAA accountable for maintaining water use efficiency. DRNA does not seem to impose consequences if the recommendations outlined in the Water Plan are not followed by fellow state agencies. As one interviewee put it, "How is it that the Governor would let one of his agencies put another agency head into jail?... the local agencies... work more on let's say a consensus basis, rather than a regulatory basis" (AAA consultant, July 2016). As a result of the hierarchical structure of agencies, agreements are reached without legal consequences. Though this informal enforcement leads to information sharing and a higher awareness of issues across agencies, limited interagency regulation has had unforeseen consequences. One interviewee attributes the reduced economic state of the island to this conflict:

"... if (they) speak up then they don't have jobs... (So) people don't say anything... everybody's just trying to do the dance. And slowly they take the whole country down" (federal employee, June 2016).

5. Discussion

Our de jure analysis revealed that equitable allocation and water use efficiency are water management targets enshrined by law in Puerto Rico; however, we found mismatches between what is written by law and what occurs in practice. Additionally, it seems that state agency accountabilities contribute to this misalignment. Agencies including DRNA, AAA, and AEE are not held accountable for enforcing their responsibilities related to water quantity management; however, there is evidence that consequences exist if state agencies do not fulfill their political responsibilities, interfering with effective water management.

Our analysis also highlights conflicting responsibilities legally assigned to DRNA, as the agency is responsible for maintaining a minimum flow to sustain ecological functions but also the prioritization of domestic human water needs. Prioritizing domestic users likely restricts DRNA's effectiveness in maintaining a minimum flow, especially when multiple sectors require access to limited water resources (i.e., during drought conditions). This may be why most instream flow protection policies do not include equitable allocation as an objective. In Arizona and Nebraska, for example, water for the environment is stated as important but comes second to domestic and agricultural water demand [46] (p. 73). Although domestic water demand has been prioritized over environmental flows in the past in Puerto Rico (see Christian et al. (2019) [39] for evidence of all discharge removed from streams), these competing mandates need to be resolved for effective environmental flow governance.

Historically, prioritizing human water demand over minimum flows incurred short-term ecological effects, as stream systems seem to recover quickly from periodic low flows [47]. However, long-term low or no flow events, such as when a large dam with no spillway is built, dramatically alter stream ecosystem functions [32,34]. As climate change is expected to intensify water scarcity events in the region [48], reductions in stream flow due to water withdrawals may be further magnified. The conflicting responsibilities of DRNA will likely need to be resolved to avoid the negative environmental impacts of reduced stream flow, especially in relation to diluting treated waste effluent entering stream systems [24].

The lack of consistent environmental flow enforcement by state agencies in Puerto Rico reflects what occurs in other states. Court rulings illustrate how citizen groups have sued agencies or water permit holders for environmental flow maintenance outlined by legislation. Washington state and Californian groups have argued for the necessity of environmental flow management using the public trust doctrine, forcing state governments to consider how private withdrawals impact property held in trust [46] (p. 64) [49]. The same legal argument could be made in Puerto Rico, as the water resources belong to the people and are entrusted to the Commonwealth for protection. Legal recourses exist for Puerto Rican citizens to hold state agencies accountable for maintaining environmental flows, which could rectify the mismatch between *de jure* and *de facto* governance.

An additional mismatch exists between AAA's legal autonomy to set domestic water rates and its inability to do so in practice. AAA's reliance on the Governor's approval to increase rates is in opposition to our *de jure* analysis, which revealed that both the federal court and Puerto Rican Supreme Court view AAA as independent of the Commonwealth government. AAA's lack of autonomy over funding has likely contributed to its USD 4.2 billion of debt [50] and hampers the agency's ability to fulfill water management targets, such as repairing leaky infrastructure in a timely manner [51]. This mismatch highlights the complex relationship between public corporations and the Commonwealth government, and how this relationship can undermine the agencies' abilities to fulfill environmental flow responsibilities.

Although our *de jure* analysis highlights existing legislation for equitable allocation and water use efficiency, what is outlined in the legislation does not consistently occur in practice. The Instream Flow Council cautioned that legislation may not be sufficient to ensure instream flows [46] (p. 61), as there are additional challenges beyond creating statutes. Studies evaluating environmental flow implementation world-wide have identified challenges such as limited political will, funding limitations [11], and institutional barriers [7]. State agencies in the southeastern U.S. struggle to maintain stream flow due to a lack of enforceable regulations, such as the minimum flow not clearly stated or only being a recommendation [11].

Our research illustrates how agency accountability has the potential to create an additional challenge for state water management agencies trying to carry out legislation. In Puerto Rico, political accountability manifests through the Governor's appointment of agency heads and subsequent ability to remove the leaders at will. Accountability to the Governor interferes with state agencies' abilities to enforce regulations on each other (e.g., DRNA fining AAA for violating their permit's stated minimum flow requirement). State agencies tasked with water management targets instead fulfill political responsibilities. However, we also do not see any evidence indicating that state agencies are rewarded when responsibilities are enforced, which may also discourage enforcement.

Actors (i.e., agencies) can be accountable to simultaneous forums, complicating the evaluation of an actor's motivation [22], and multiple accountabilities can lead to ineffective actors [52]. In Puerto Rico, accountability to the Governor seems to limit the ability of state agencies to carry out their legally assigned responsibilities (i.e., raising water rates to increase water use efficiency). However, politics seem to influence water management decisions throughout the U.S. In Georgia, for example, politics drive water management decisions and agricultural water users are prioritized [17]. Though federal agencies could enforce regulations counter to state political will since they are not accountable to the Governor, there are limited channels for federal agencies to engage in environmental flow governance.

Ecologists recognize the importance of flow in Puerto Rican streams to maintain aquatic biota [25,34]. Indeed, research has shown that prolonged minimum flows (i.e., below the flow exceeded 50% of the time) could be more detrimental to migratory animals than infrequent low flow periods [53], suggesting maintaining a minimum flow will not be sufficient to sustain migratory populations. If the current Q99 regulation cannot be effectively enforced on the island, it seems likely that any future regulations extending legal protection beyond a minimum flow will also be challenging to maintain. Perhaps a more nontraditional route of securing water for the environment would be more effective, such as creating a legal right to water for the environment itself [54] (p. 361). Legally creating the environment as a water user could serve to maintain water within streams and is being explored in other systems around the world [54].

Traditionally, ecologists have focused on identifying the amount of flow necessary to maintain a functioning stream ecosystem [55] and making useful legislation recommendations [9]. However, the issue of whether ecological flow maintenance occurs when protective legislation is in place is beginning to be addressed [56]. Opportunities abound to understand whether mandated flows are sufficient to maintain ecosystem function [2] and to identify the factors that make enforcement effective. Our identification of state agency accountability represents a novel approach to exploring limitations in effective environmental flow management, as accountability directly influences the actions of agencies [20]. Though state agencies in Puerto Rico seem to meet the water governance targets (i.e., maintain minimum flows) when feasible, accountability for legislative directives may provide a necessary incentive to consistently enforce regulations. Though there are additional challenges to enforcing environmental flows, we believe that our findings contribute to how environmental flows can be effectively maintained and to the noted gap of identifying accountability within governance systems [52]. We can achieve a deeper understanding of how environmental flows are managed, facilitating ecologists' desire to make relevant legislation recommendations [5], by evaluating the accountability of the agencies tasked with enforcing environmental flow regulations.

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