WATER WISE CALIFORNIANS: AN ANALYSIS OF THE ENDURING EFFECTIVENESS OF STATEWIDE WATER REDUCTION REQUESTS

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MASTER OF PUBLIC POLICY AND ADMINISTRATION

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Executive Summary

This paper examines the enduring effectiveness of voluntary water reduction calls in California. For more than two decades California governors have issued statewide water reduction requests as a first line of defense to drought. Governors subsequently imposed mandatory water restrictions and offered assistance in reducing water use, including state rebates to replace lawns with drought-tolerant landscaping and upgrade appliances to more water-efficient models. Permanent switches such as these make future water cuts to the same degree more difficult. Given California's Mediterranean climate, the state will inevitably face drought again. Therefore, it is important to evaluate whether uniform statewide water reduction requests are feasible and effective. This paper analyzes data from the California State Water Board and runs two linear regression analyses to test whether 1) the presence of voluntary water reduction calls had any effect on statewide water use levels and 2) whether the amount of water a supplier used before the most recent voluntary reduction call had an impact on the percentage reduction the water supplier achieved. This paper exclusively examines residential water use on a per capita basis. Findings suggest that the highest water users in California prior to a drought will conserve the least during a drought. The results of this study can inform future water restriction policies. Statewide water reductions are likely to be effective, but not equally so across California. Targeted approaches that ask for water reductions from the lowest residential water users are likely to provide the greatest water savings. However, reduction requests accompanied with education on water conservation may influence the highest water users to increase their reductions.

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Introduction

Many places with dry and aired climates or with highly seasonal precipitation have turned to urban water use restrictions as a method of preserving adequate water supply in warm, dry months. Among these places is California; the state's unique Mediterranean climate is characterized by cool, wet winters and hot, dry summers and is prone to prolonged periods of drought. Now, with anthropogenic climate change intensifying, droughts are becoming more frequent and more severe. Prolonged droughts strain water resources in a state of 40 million people and a large agricultural industry, prompting governors to request and require local jurisdictions to reduce their water use. Oftentimes, state scientists forecast dry conditions and governors can simply *request* water use reductions, before requiring them if necessary.

Studying water use is of great importance in California, which has long been home to intense battles for water. Simply put, there is more demand than there is water. This is evident in the more-than-century-long struggle among urban, environmental, and agricultural water interests. This struggle has resulted in water use reductions in recent years and as the expected frequency of drought increases, it is important to understand how water use levels in times without reductions affect water use levels when the governor does make a request for reduction in use. As Californians swap out appliances for more water-efficient versions, change their landscaping to cut water use, and alter their daily habits to conserve water, it is very likely that they increasingly have fewer ways to conserve water when the governor issues voluntary reduction requests.

During two of California's most recent severe droughts (2014-2016 and 2021-2023) Governors Brown and Newsom issued voluntary water use reduction requests. In January 2014, after what was then the driest year on record, Governor Jerry Brown called for a twenty percent voluntary reduction in water use (Brown, 2014) and then followed up in April 2015 with the first-ever mandatory statewide water reduction aimed at urban water use (Brown, 2015). The mandate called for a twenty-five percent reduction and came with reporting requirements for local agencies and enforcement actions for those non-compliant. The mandate came with practical steps to reduce water usage, including replacing lawns with drought-tolerant landscaping, offering consumer rebates for replacing old appliances with more water-efficient versions, prohibiting new developments from irrigating with potable water unless using target drip irrigation, a ban on watering ornamental grass on public street medians, and specific mandated water cuts for large grassy areas (e.g. golf courses and cemeteries).

Residents successfully reduced water use by twenty-five percent in compliance with the Governor's mandate (Porse, 2023). Some of the reduction tactics were temporary and water use often rebounds after restrictions are gone (Gonzales and Ajami, 2017, Mitchell et al., 2017), but some of the tactics, notably replacing appliances and investing in drought-tolerant landscaping, remain after the reduction mandates are rescinded. Therefore, as some journalists have already reported, it may be hard for residents to make large reductions in their water use as future voluntary reduction requests come (Becker, 2023).

In 2021, Governor Gavin Newsom requested voluntary water reductions of fifteen percent statewide (Newsom, 2021). In August 2021, he threatened that mandatory restrictions could be necessary, but the drought never reached enough severity for him to implement such (Rogers, 2021). He did not end the voluntary fifteen percent water conservation target until March 2023, after a winter of heavy precipitation (Newsom, 2023). Mother Nature saved

Californians in 2023; the state only achieved a seven percent reduction, not the fifteen percent Newsom was looking for (Smith et. al, 2023).

Comments from Jennifer Cusack, Director of Public and Government Affairs with the Hi-Desert Water District in Yucca Valley could explain the current situation well: “There’s not a lot of opportunities for savings in our community, because we’ve done so much already. A lot of folks don’t even irrigate their homes. They have dirt lots or maybe some trees.” (Becker, 2023). Cusack’s argument is at the crux of what my research aims to determine. Are some areas of the state conserving little when the governor makes a voluntary request because they simply have already conserved nearly as much as they can?

If highly conservative water districts are already saving nearly the maximum amount and other districts continue to use water liberally under voluntary calls for reduction, then the governor’s requests will be in vain. If voluntary requests are not effective enough, he will likely turn to mandatory orders. However, one-size-fits-all statewide mandatory restrictions could be infeasible for already conservative water districts. Therefore, it is crucial to explore the regional effectiveness of voluntary use restrictions. This type of research may guide future gubernatorial action.

Mandatory and voluntary water use restrictions are widely used across the world and several scholars have researched their effectiveness is similar climates, including Colorado and Australia (Copper, 2017; Kenney et. al, 2004). There exist studies on their effectiveness in California as well (Palazzo et. al, 2017), but there is a distinct lack of empirical studies that research how effectiveness varies across California water districts based on per-capita usage before voluntary reduction requests. Therefore, this paper addresses a gap in the literature and explores this question: *How do pre-reduction per-capita water use levels affect water saving percentages in response to gubernatorial voluntary water use reduction requests among California water suppliers?*

Given previous research that shows that both voluntary and mandatory water use reductions are effective (Halich & Stephenson, 2009; Kenney et. al, 2004 Mini et. al, 2015), and that local messaging urging water consciousness is even more effective (Halich & Stephenson, 2009; Palazzo et. al, 2017), I predict that water districts with previously low levels of water use per capita reduce their water use by a greater percentage than water districts with high levels of water use, when asked to do so by the governor.

This paper provides a brief history of the use of water reduction requests in California and explains the need for a study of their effectiveness long-term. I review existing literature on the topic and identify the gap that this study fills. Then, I detail my data and research method. In this paper I run a preliminary test to determine whether the presence of voluntary water reductions prompted water conservation at all during the most recent drought. I then run the second and primary regression to determine what, if any, affect water use levels in the months immediately preceding the 2021-2023 voluntary reduction request had on the percentage water suppliers reduced. I interpret the results of the study and their implications for California water policy. Finally, I underscore the importance of this research, acknowledge the limitations of my study, and suggest future research topics in a brief conclusion.

Literature Review

Scholars have examined the effectiveness of water use reductions or restrictions in residential areas across the globe, including California. Scholarship extensively shows that mandatory water use reductions are effective (Halich & Stephenson, 2009; Kenney et. al, 2004; Mini et. al, 2015). Kenney, Klein, and Clark (2004) review residential outdoor water conservation in the Denver metro area during the 2002 drought. The scholars reviewed eight municipal water providers and found only some had drought plans. From May to August 2022 all eight municipalities placed restrictions on outdoor water use, including lawn watering, car washing, and filling swimming pools. Five of the eight municipalities started with voluntary restrictions and then moved to mandatory restriction; whereas three municipalities maintained mandatory restrictions the entire summer. Under voluntary restrictions, cites saw modest reductions of as much as seven percent (and most far less) and one even experienced an increase in water usage. However, under mandatory restrictions cities saw reductions of thirteen to fifty-five percent. The greatest reductions came with the most stringent restrictions: limiting lawn watering to once a week, versus two or three times (Kenney et. al, 2004).

Scholarship not only shows that mandatory reductions are effective, but much more so than voluntary reductions. Mini, Hogue, and Pincetl (2015) study water conservation in Los Angeles; their findings confirm the work of Kenney and his colleagues (2004) from a decade prior. Mini and colleagues examine the effectiveness of water conservation measures on summer residential water use in Los Angeles. Their work focuses on municipal restrictions, most of them for outdoor watering, from 2000-2010. Like California governors did statewide in subsequent years, the Los Angeles mayor implemented voluntary water reductions of ten percent in June 2007, moved to mandatory restrictions in August 2008, and tightened the restrictions in June 2009 and simultaneously introduced a conservation price incentive (Mini et. al, 2015). The City offered rebates for water-saving devices, similar to what California did statewide in 2014. The study reveals that mandatory restrictions are more effective than voluntary restrictions in compelling residents to reduce water usage. Mandatory restrictions and price incentives reduced water use by a maximum of twenty-three percent, whereas there was no difference in city-wide residential water use under voluntary restrictions (Mini et. al, 2015). This study is particularly valuable for my research as it is focused solely on residential water use and examines the largest city in California.

The varying effects of voluntary and mandatory water use restrictions can be drawn from studies that study local differences in the enforcement of restrictions and the environment in which they are implemented. For example, Halich and Stephenson (2009) primarily study the impact of information and enforcement on water reduction, but their work also offers insight on the differing effectiveness of voluntary and mandatory water use restrictions. They find that residential water use reduction increased with increased levels of information and enforcement. For voluntary reductions, water use decreased by zero to seven percent, whereas it decreased from four to twenty-two percent under mandatory reductions (Halich & Stephenson, 2009). The work of all of these authors (Halich & Stephenson, 2009; Kenney et. al, 2004; Mini et. al, 2015) reveals a distinctly positive relationship between mandatory water use restrictions and water conservation. Additionally, the scholarship consistently shows that mandatory reductions are much more effective than voluntary reductions. Knowing that humans are less likely to reduce their water use when not compelled, my study looks at the degree to which, and where, this phenomenon occurs during times of voluntary reductions across California.

Palazzo and colleagues (2017) explore the effect geographic features, including drought severity, have on a jurisdiction's willingness to conserve water. They study urban California water districts' water use during drought in 2015. The Governor imposed a statewide mandatory reduction, but assigned differing conservation targets to each urban water district, ranging from four to thirty six percent (Palazzo et. al, 2017). The state did achieve its overall goal of twenty-five percent reduction, but only half of urban water districts reached their individual conservation target. They find that biophysical features, namely level of drought severity, socioeconomic status, and institutional structure impact water conservation levels. The more severe a drought is, the more affluent water district residents are, and the more regionally connected a water system is, the more likely the district is to reach its conservation levels.

While there is plentiful scholarship, as discussed, that explores the difference between mandatory and voluntary restrictions, there is a notable lack of scholarship on the effectiveness of calls for voluntary water use alone. However, some scholars find weaker, yet still positive correlations between voluntary reductions and water conservation (Halich & Stephenson, 2009; Krohn, 2019; Palazzo et. al, 2017). In many cases, governmental requests for a voluntary reduction in water use are more effective when combined with strong public messaging (Halich & Stephenson, 2009) or regional collaboration (Palazzo et. al, 2017).

Mahler (2021) identifies a willingness from individuals to voluntarily partake in several water conservation and preservation activities over a multi-decade period. While uptake was not immediate, after more than three decades, at least ninety percent of Pacific Northwest residents engaged in voluntary measures to protect their water quality. In 1988, only sixteen percent of residents across Alaska, Idaho, Oregon, and Washington had taken one voluntary action to reduce water use. Thirty-two years later, in 2019, ninety two percent of residents had voluntarily reduced water use in at least one way, and seventy two percent had reduced water use in more than one way (Mahler, 2021). This study does not examine a region impacted by drought in a way similar to California, but it does show residents increased willingness to reduce water use with increased requests for such.

In contrast, a study from Southeast Florida finds that water restrictions are not always effective and many residents continue to over-water, despite calls to cut back. Survis and Root (2012) examine whether Southeast Florida residents successfully reduced water use under outdoor watering restrictions. They study the effectiveness of restrictions in an unconventional way for the region: measuring effectiveness of the restrictions by looking at water use rather than compliance with the watering restrictions. Their work reveals that although residents largely complied with the restricted watering scheduled, they did not reduce overall water use by a significant amount and grossly over-watered their lawns (Survis & Root, 2012). Therefore, the scholars recommend policymakers set reduction percentage goals rather than, or in addition to, restricting water use activities. Statewide, governors have primarily asked Californians to reduce water by a specified percent and local jurisdictions have implemented restrictions on activities. Water districts with no local reduction goal may be less likely to reduce water use despite restrictions on water use activities.

These studies detailing some initial and persistent reluctance to comply with voluntary requests informs my hypothesis:

> H: Water agencies with lower water use prior to reduction request have higher percentage of reduction in water use than water agencies with high water use prior to reduction.

The assumption behind this hypothesis is that jurisdictions that have little interest in water conservation will not heed, or will heed at very low rates, calls for water use reduction when they are voluntary and not mandatory.

Water is a scare resource globally and as these studies show, many states, cities, and water districts attempt to limit residential consumption. Scholars focus on the effectiveness of mandatory restrictions much more than voluntary restrictions and there is a distinct lack of studies on the effectiveness of restrictions statewide during California's two most recent droughts. No empirical study has examined the enduring effectiveness of gubernatorial water restrictions in California as residents make permanent alterations to their water use. Therefore, this paper fills a critical gap in the literature to inform wise and effective executive water policy.

Data & Methodology

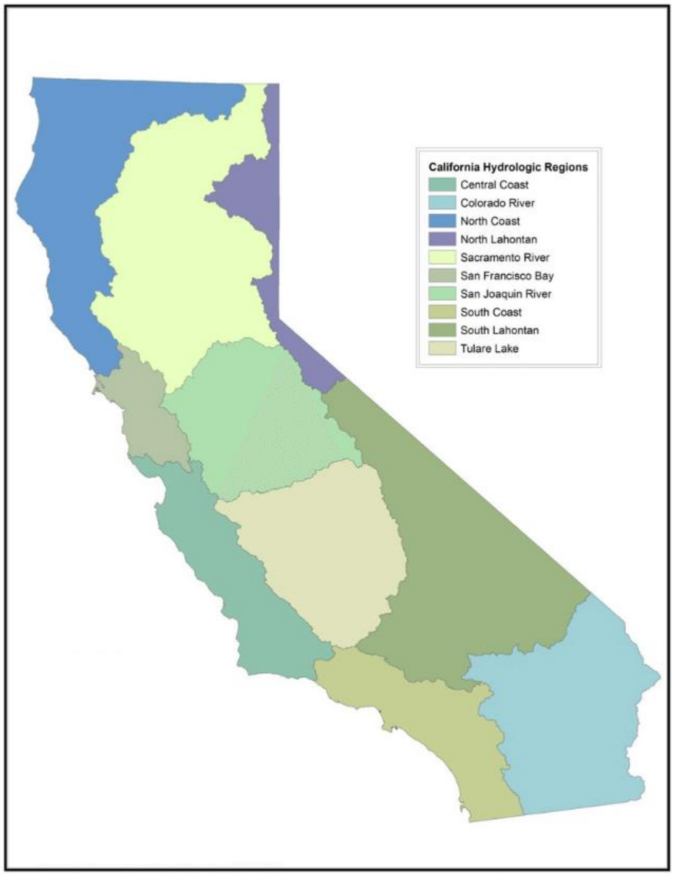
To determine the regional effectiveness of calls for voluntary water reductions from California Governors, I analyze data on residential water use compiled by the California State Water Resources Control Board (Water Board). Information is reported monthly by individual water suppliers to the Water Board and includes data on what the reporting month is, the gallons per capita per day (gpcd) used by the water supplier, the population size served, the county or counties it operates within, the hydrologic region and climate zone it is within, whether the supplier is under a county drought declaration, and whether the county is operating with a shortage plan for a shortage greater than ten percent. Unfortunately, many suppliers do not report wither they are under a drought declaration nor whether they are operating on a shortage plan, which makes these data points unusable as control variables.

Before running the primary regression of my study, I run a preliminary regression to determine whether water suppliers reduced water use during the post-reduction call. For this, I use the raw monthly data from all California water suppliers, which totals 24,263 data points between the pre-restriction months of January 2018 to May 2021 and the post-restriction months of August 2021 to May 2023. The independent variable is pre-reduction water use and the dependent variable is post-reduction water use. I limit the control variables for the initial test to just hydrologic regions and population for the sake of simplicity. With a continuous and numerical, I run a linear regression analysis. Below is a summary statistics table for the data used for the initial linear regression and a map of the state's hydrologic regions.

Table 1. Summary of Statistics

Category	Variable	N	Mean	SD	Min	Max
Outcome Variables	Post Month gpcd	24,263	97.7066	53.53762	10.6403	565.642
Explanatory Variables	Post Water Restriction Month	24,263	0.3602192	0.4800738	0	1
	Hydrologic Region					
	Central Coast	24,263	0.0773606	0.2671682	0	1
	Colorado River	24,263	0.0372584	0.1893982	0	1
	North Coast	24,263	0.0386185	0.1926879	0	1
	North Lahontan	24,263	0.0119936	0.1088587	0	1
	Sacramento River	24,263	0.1052632	0.3068985	0	1
	San Francisco Bay	24,263	0.1183695	0.3230518	0	1
	San Joaquin River	24,263	0.0691176	0.2536592	0	1
	South Coast	24.263	0.4266991	0.494608	0	1
	South Lahontan	24,263	0.0422042	0.2010588	0	1
	Tulare Lake	24,263	0.0731154	0.2603313	0	1
	Population	24,263	92,874.7	243,382.4	112	4,124,338

Figure 1. California Hydrologic Regions



Source: UC Davis Water Management Research Group

Figure 1 displays California's ten hydrologic regions. The hydrologic regions represent natural regions where rivers and streams flow into the same aquifer system and often have the same output point (Escriva-Bou, McCann, Hanak, Lund, and Gray, 2016). It is important to understand how each region impacts water use given the great geographic variance in water supply and sources. For example, suppliers in some regions may primarily use surface water, whereas suppliers in other regions rely heavily on groundwater. Still others may source water from water resources shared with other states.

After running the preliminary regression to determine whether there was on overall trend of water conservation during the voluntary reduction period, I ran a primary regression to determine if and how pre-restriction water use levels impact the percentage change in water use. I organize raw data from the Water Board by averaging both the pre- and post- reduction gpcd for each water supplier and calculating the percentage change between the two numbers. I also average the population for each supplier over the entire observed period, January 2018 to May 2021 and August 2021 to May 2023. The data captures water use for 410 suppliers. For the primary regression, the independent variable remains pre-reduction water use, whereas the dependent variable is percentage change. Because my dependent variable is continuous and numerical, I use linear regression to analyze the data.

I control for county, population, hydrologic region, and climate zone. I create a dummy variable for post water restriction months, with 0 indicating it is a month before the reduction call and 1 indicating it is a moth after the initial reduction call. Likewise, I create dummy variables for each of the ten hydrologic regions and sixteen climate regions in the state. Included below is a summary of statistics table demonstrating these data points, and a map of the state's climate zones.

Table 2. Summary of Statistics

Category	Variable	N	Mean	SD	Min	Max
Outcome Variables	Percent Change	410	-6.940708	11.74438	-80.0478	64.22649
Explanatory Variables	Pre-Water Restriction Average gpcd	410	100.7338	42.29425	30.1082	346.6122
	County					
	Alameda	410	0.0121951	0.1098902	0	1
	Alameda, Contra Costa	410	0.001878	0.0697576	0	1
	Alameda, San Francisco	410	0.002439	0.0493865	0	1
	Amador	410	0.002439	0.0493895	0	1
	Butte	410	0.0121951	0.1098902	0	1
	Butte, Glenn	410	0.002439	0.043865	0	1
	Calaveras	410	0.002439	0.043865	0	1

Table 2. Summary of Statistics (continued)

Category	Variable	N	Mean	SD	Min	Max
Explanatory Variables	Contra Costa	410	0.0195122	0.1384855	0	1
	Del Norte	410	0.002439	0.0493865	0	1
	El Dorado	410	0.0073171	0.0853305	0	1
	El Dorado, Placer	410	0.002439	0.0493865	0	1
	Fresno	410	0.0243902	0.1544459	0	1
	Glenn	410	0.002439	0.0493865	0	1
	Humboldt	410	0.0146341	0.12023	0	1
	Imperial	410	0.0097561	0.09841	0	1
	Imperial, Riverside	410	0.002439	0.0493865	0	1
	Kern	410	0.0365854	0.1879709	0	1
	Kern, Los Angeles	410	0.002439	0.0493865	0	1
	Kern, San Bernardino	410	0.002439	0.0493865	0	1
	Kern, Tulare	410	0.002439	0.0493865	0	1
	Kings	410	0.0073171	0.0853305	0	1
	Lake, Marin, Sonoma	410	0.002439	0.0493865	0	1
	Lassen	410	0.002439	0.0493865	0	1
	Los Angeles	410	0.1902439	0.392973	0	1
	Los Angeles, Ventura	410	0.002439	0.0493865	0	1
	Madera	410	0.004878	0.0697576	0	1
	Marin	410	0.002439	0.0493865	0	1
	Marin, Sonoma	410	0.002439	0.0493865	0	1
	Mendocino	410	0.002439	0.0493865	0	1
	Merced	410	0.0097561	0.09841	0	1
	Mono	410	0.002439	0.0493865	0	1
	Monterey	410	0.0170732	0.1297024	0	1
	Napa	410	0.004878	0.0697576	0	1
	Nevada, Placer	410	0.004878	0.0697576	0	1
	Orange	410	0.0707317	.02566894	0	1
	Placer	410	0.0097561	0.09841	0	1
	Placer, Sacramento	410	0.004878	0.0697576	0	1
	Riverside	410	0.0512195	0.2207145	0	1
	Riverside, San Bernardino	410	0.0097561	0.09841	0	1
	Sacramento	410	0.0317073	0.1754338	0	1
	San Benito	410	0.004878	0.0697576	0	1
	San Bernardino	410	0.0682927	0.2525557	0	1
	San Diego	410	0.0512195	0.2207145	0	1
	San Joaquin	410	0.0195122	0.1384855	0	1
	San Luis Obispo	410	0.0219512	0.1467033	0	1
	San Mateo	410	0.0390244	0.1938896	0	1

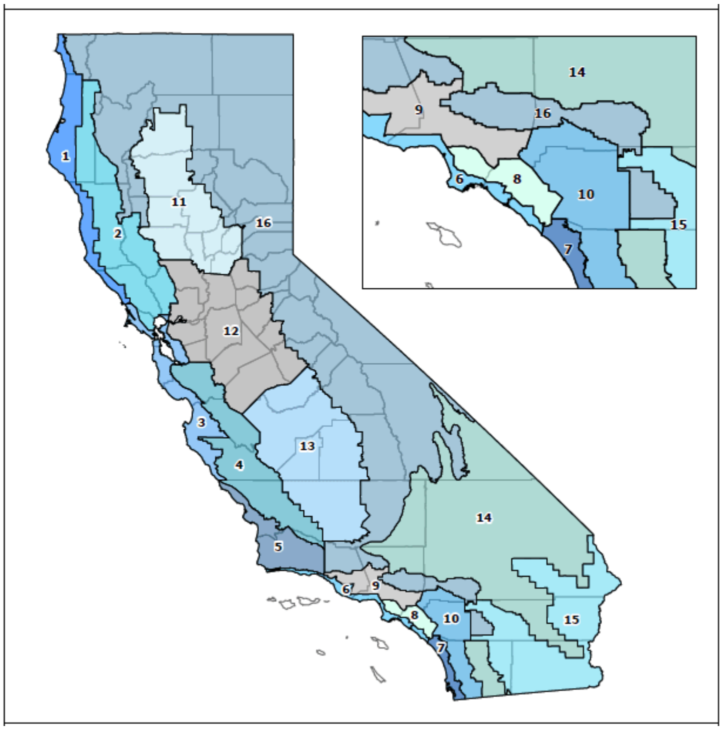
Table 2. Summary of Statistics (continued)

Category	Variable	N	Mean	SD	Min	Max
Explanatory Variable	Santa Barbara	410	0.0170732	0.1297024	0	1
	Santa Clara	410	0.0268293	0.1617816	0	1
	Santa Cruz	410	0.0121951	0.1098902	0	1
	Shasta	410	0.0097561	0.09841	0	1
	Siskiyou	410	0.002439	0.0493565	0	1
	Solano	410	0.0170732	0.1297024	0	1
	Sonoma	410	0.0219512	0.1467033	0	1
	Stanislaus	410	0.0170792	0.1297024	0	1
	Sutter	410	0.002439	0.04938902	0	1
	Tehama	410	0.002439	0.04938902	0	1
	Tulare	410	0.0121951	0.1098902	0	1
	Tuolumne	410	0.004878	0.0697576	0	1
	Ventura	410	0.0341463	0.1818269	0	1
	Yolo	410	0.004878	0.0697576	0	1
	Yuba	410	0.0073171	0.0853305	0	1
	Hydrologic Region					
	Central Coast	410	0.0780488	0.2685761	0	1
	Colorado River	410	0.0365854	0.1879709	0	1
	North Coast	410	0.0390244	0.1938869	0	1
	North Lahontan	410	0.0121951	0.1098902	0	1
	Sacramento River	410	0.104878	0.3067706	0	1
	San Francisco Bay	410	0.1146341	0.3189691	0	1
	San Joaquin River	410	0.0707317	0.2566849	0	1
	South Coast	410	0.4243902	0.494854	0	1
	South Lahontan	410	0.0414634	0.199603	0	1
	Tulare Lake	410	0.0780488	0.2685761	0	1
	Climate Region					
	One	410	0.0170732	0.1297024	0	1
	Two	410	0.0341463	0.1818269	0	1
	Three	410	0.0756098	0.2646957	0	1
	Four	410	0.0414634	0.199603	0	1
	Five	410	0.0243902	0.1544459	0	1
	Six	410	0.0780488	0.2685761	0	1
	Seven	410	0.0243902	0.1544459	0	1
	Eight	410	0.0926829	0.2903419	0	1
	Nine	410	0.1268293	0.3331882	0	1
	Ten	410	0.104878	0.3067706	0	1
	Eleven	410	0.0512195	0.2207145	0	1
	Twelve	410	0.1390244	0.3463947	0	1

Table 2. Summary of Statistics (continued)

Category	Variable	N	Mean	SD	Min	Max
Explanatory	Thirteen	410	0.0829268	0.2761085	0	1
Variable	Fourteen	410	0.0739024	0.2051284	0	1
	Fifteen	410	0.0292683	0.1687635	0	1
	Sixteen	410	0.0341463	0.1818269	0	1
	Population	410	90,120.6	237,430.1	112	4,001,409

Figure 2. California Climate Regions



Source: California Energy Commission

Figure 2 depicts California's sixteen climate zones. The California Energy Commission publishes climate zones to guide building standards. While not directly related to water, climate zones are integral to water supply and availability because, among many factors, they reveal how much precipitation a zone receives and whether there is a hot and aired climate that causes surface water to evaporate quickly.

Findings

Using the data summarized in Table 1, I run a preliminary regression to determine if voluntary reduction requests are have any influence on water use. Table 3 shows that the voluntary water reduction requests are likely to decrease the amount of water that Californians used, by 7.42gpcd. Water use is likely to decrease among water suppliers across *most* of the state. The hydrologic region the water supplier is within plays a role and is statistically significant for each region. All hydrologic regions except Colorado River and Sacramento River are likely to see wate reductions at the statistically significant level of 0.001. The Sacramento River hydrologic region is likely to see reductions at a statistically significant level of 0.10. Interestingly, residents of a water supplier in the Colorado River hydrologic region are more likely to *increase* their water use by 9.88gpcd.

When all other factors are held constant, the population of the water district has minimal influence whether a water district decreased its water use. The coefficient is so small that it is rounded to 0.00, but its influence is statistically significant at the 0.001 level. Population positively influences water use, meaning the larger the customer population of the water supplier, the more water customers are likely to use per capita. My variables explain about thirteen percent of my results, as indicated by the R-squared number. Table 3 displays the results of the linear regression analysis in numerical form.

Table 3. OLS Regression Table

DV: Monthly water use (gpcd)	
Variable	Coefficient (Standard Error)
Post Month	-7.42*** (0.67)
Central Coast	-49.77*** (1.66)
Colorado River	9.88*** (2.01)
North Coast	-55.76*** (2.02)
North Lahontan	-24.68*** (3.17)
Sacramento River	-2.86† (1.55)
San Francisco Bay	-53.15*** (1.52)
San Joaquin River	-16.38*** (1.71)
South Coast	-30.23*** (1.29)
South Lahontan	-23.77*** (1.97)
Population	0.00*** (1.22)
………………………………………………...	………………………………………………
Constant	129.23***
N	24,263
R-squared	0.13

Note: †ρ<.1; *ρ<.05; **ρ<.01; ***ρ<.001

As the overall presence of voluntary water restrictions is likely to reduce water use, I run a secondary linear regression to analyze my research questions and determine what, if any, affect pre-reduction water use has on percentage change in water use during voluntary calls for water reduction. I use the data summarized in Table 2 to conduct my primary regression analysis. The regression shows that water use levels before the reduction call *do* impact the magnitude of water conservation. Table 4 displays the results of this second regression.

Table 4. OLS Regression Table

DV: Percentage change (gpcd) Variable	Coefficient (Standard Error)
Pre-Month	-0.06*** (0.02)
Population (log)	-1.03* (0.61)
Central Coast	-35.25† (24.28)
Colorado River	-11.72† (14.92)
North Coast	-38.88† (23.99)
North Lahontan	-51.65† (19.67)
Sacramento River	-42.23* (21.43)
San Francisco Bay	-51.65** (22.72)
San Joaquin River	-42.25* (23.93)
South Coast	-13.89† (11.98)
South Lahontan	-3.01 (12.23)
Climate Zone 1	-16.37† (22.46)
Climate Zone 2	-10.38 (21.28)
Climate Zone 3	-12.39† (9.73)
Climate Zone 4	-14.22† (9.19)
Climate Zone 5	-22.41* (9.50)
Climate Zone 6	-3.44 (8.35)
Climate Zone 7	0.37 (8.56)
Climate Zone 8	-1.53 (8.46)
Climate Zone 9	-4.01 (8.34)
Climate Zone 10	-1.34 (6.98)
Climate Zone 11	-2.23 (15.43)
Climate Zone 12	-19.75* (10.55)
Climate Zone 13	-10.22† (7.81)
Climate Zone 14	-9.08† (7.12)
Climate Zone 15	2.71 (11.31)
Counties	Included
………………………………………………	………………………………………………
Constant	41.14*
N	410
R-squared	0.32
Adjusted R-squared	0.14

Note: †ρ<.1; *ρ<.05; **ρ<.01; ***ρ<.001

Overall, the more water a supplier uses before voluntary reduction calls, the smaller the percentage of reduction is. The less gpcd a supplier used before the reduction recall, the less likely they are to decrease their water use, by a magnitude of 0.06 percentage points. This is statistically significant at the 0.001 level. This means that water suppliers that use more gpcd in the pre-reduction period are not likely to reduce their water use under the voluntary restrictions at as great a percentage as suppliers who use less in the pre-reduction period.

Population is also a strong predictor of water conservation. The regression shows that the larger the population the water supplier serves, the less water the supplier is likely to conserve. Nearly all hydrologic regions and a little less than half of the climate zones also influence water reduction at statistically significant levels. To varying degrees, water suppliers in all regions and zones with statistically significant influence are likely to reduce water use. Most counties have a statistically insignificant impact on the percentage water suppliers reduce. Ultimately, the dependent variable much more strongly predicts water reduction percentages than counties do as control variables. Table 4 displays the results of the linear regression in numerical form.

Discussion

The results of this study reveal that, overall, voluntary water reduction requests are likely to be effective in California as the regression shows that residents tend to reduce water when asked, even if there are not incentives or consequences applied. Furthermore, the most water conscious suppliers in California before the most recent drought continue to be the most water conscious suppliers when asked to reduce water usage. Despite making severe cuts to water usage after the 2014-2016 drought, the lowest water users are still likely to manage to cut water usage by a greater percentage than the highest users before the voluntary restrictions.

Governors' tactics of issuing voluntary reduction requests is overall effective, if uneven across the state.

In examining the results of the first regression, clearly voluntary water reductions are effective in reducing residential water use. Californians heeded Governor Newsom's requests to reduce their water use during the most recent 2021-24 drought. Water suppliers across nearly every hydrologic region managed to lessen their residential water use. Residents had practice with water conservation only five years prior during the 2014-16 drought and likely had an easy time revering to shorter showers, limited lawn watering, and fewer car washes, among other changes. It could reasonably expected that Californians might have been burnt out of water conservation and reluctant to cut back when the governor asked them too, but the data show that is largely not the case.

Water conservation is, however, not the trend in all parts of the state. In the Colorado River hydrologic region water suppliers are likely to increase their water usage rather than decrease it. This is likely due to inter-state water politics that incentivize high water use from the Colorado River. Seven states draw water from the Colorado River and the allocated acre feet of water is greater than what the river can supply, so states are in intense negotiations over new allocations (Flavelle, 2024). If California cannot prove it is using most or all of its existing allocation, it will likely receive a smaller allocation. Therefore, there is a unique incentive for water suppliers in the Colorado River region to increase water use among their customer base, even while the rest of the state is decreasing use.

Turning to the primary regression test, analyzing whether pre-reduction request water use levels impact the percentage a water supplier reduced during the 2021-24 drought, the findings indicate that the most conservative suppliers before the reduction request tended to continue to be the most water conscious. Despite already using the lowest water per person, such water supplier customers managed to cut back at greater rates than the highest water users in the state. Although the highest water users conceivably have more opportunity to conserve, they did not. My results suggest that water conservation is more dependent on mindset and willingness than pure capability.

This is consistent with the findings of Mahler (2021) that people who have the capacity to conserve may not always do such immediately. However, with multiple asks and over time, their willingness to do so is likely to increase. Therefore, I expect that voluntary water requests may be increasingly effective in California with subsequent droughts. Halich & Stephenson (2009) and Palazzo et. al (2017) find that local messaging about water conservation increased resident's willingness to conserve. California Governors could partner with local water suppliers to provide public messaging on the importance of water conservation to increase compliance with the reduction requests among residents in high water use jurisdictions.

This study does not make claims about the individual circumstances and capabilities of water suppliers, so it is possible that some conservative suppliers are unable to reduce water use by much more. However, the overall trend across California is that that is not the case. Even the lowest water users complied with the voluntary requests and did so to a greater degree than the highest water users. Conversely, some high water users may also be incapable of achieving high rates of reduction due to circumstances not captured in this study. Nevertheless, the results of my study support California governors' decisions to make statewide water reduction requests. However, my findings also indicate that more targeted reduction requests could be *more* effective than across-the-board reduction percents.

Different reduction request targets tailored for different water suppliers may be more effective in reducing overall residential water use in California. At the time of considering water restrictions, governors could continue to ask for at least fifteen percent conservation from the highest water users in the state as residents in those jurisdictions will likely continue to make modest reductions in pursuit of the goal. However, water savings could be maximized by requesting higher conservation percentages from the lowest water users, as this study indicates that such suppliers will respond with fervor and may be able to achieve greater savings.

This study does not examine the effectiveness of mandatory water reductions, but mandatory reductions may be just as effective, if not more effective, if implemented statewide than voluntary requests. Previous literature indicates that mandatory requests are overall more effective in compelling water conservation (Halich & Stephenson, 2009; Kenney et. al, 2004; Mini et. al, 2015). It is reasonable to assume that the lowest water users would achieve at least equal results and the highest water users may be spurred to make greater inroads in conservation when faced with negative consequences if reduction targets are not met.

Conclusion

California is frequently plagued by drought, requiring gubernatorial action to ensure adequate water supply for all residents. During the two most recent droughts, two different California governors have each requested voluntary water reductions followed by mandatory restrictions. Government rebates for permanent water saving measures accompanied restrictions during the 2014-16 drought. Despite many residents making permanent switches to their appliances, landscaping, and habits, Governor Newsom followed the same pattern as Governor Brown six years before him and requested voluntary water reductions. Some particularly water conscious water suppliers pushed back on the across-the-board water reductions, fearing negative consequences if they were not able to comply with mandatory restrictions. While reduction capabilities vary from supplier to supplier, this study shows that, overall, the lowest water users achieve the highest percentage of reductions, showing that recent gubernatorial strategies are effective after multiple drought cycles and water conservation efforts.

California policy makers can look to this study to inform strategies for water conservation during drought. My study suggests that the most effective voluntary requests will be in places where there is already low per capita water use, as residents are already invested in water conservation. Therefore, while statewide reduction requests are likely to be effective, more targeted asks to the lowest per capital users are likely to provide the most cost-beneficial results. Expending more resources to provide educational materials along with asking for voluntary reductions of the highest water users has the potential to unlock greater reductions from residents who may otherwise be reluctant to comply with the requests. This strategy holds significant potential water savings for the state, but comes at a higher cost.

This paper is limited in scope. My research is only on residential water use in California; trends in agricultural and environmental water use may vary greatly. Additionally, while the data used for this study captures a majority of California residents, it only comprises the 410 water suppliers that report to the State Water Board; it does not include information residents who source their water from domestic wells. As stated in the data and methodology section of this paper, this study does not consider whether local drought declarations or water restrictions impacted the effectiveness of gubernatorial water reduction requests. Unfortunately, there is not consistent reporting of such to the State Water Board. To increase research potential that could inform policy, the Water Board could require more consistent reporting of those data points. While there are many limitations to this study, it fills a niche gap in the literature of water conservation policy. My study reveals unique trends among California water agencies during recent statewide voluntary water reduction requests, which can be used by policy makers, especially governors, to tailor the water conservation strategies used during future droughts.

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