The Slow Dividend: Dam Removal and the Delayed Recovery of River Water Quality

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Abstract

The United States removes over 100 dams annually, spending billions on ecological restoration—yet no large-scale causal evidence exists on whether removal actually improves physical water quality. I exploit the staggered timing of 1,341 dam removals (2000–2020) matched to 295 USGS continuous stream gauges, using Sun-Abraham heterogeneity-robust estimation. Dam removal reduces downstream water temperature by 0.24°C on average, with effects growing to 0.84°C a decade after removal—a pattern I call the *slow dividend*. Dissolved oxygen increases by 0.21 mg/L. Conventional two-way fixed effects attenuates these estimates by 50%, masking the compounding ecological recovery. A randomized placebo test on untreated gauges produces near-zero effects. These findings provide the first large-N evidence that dam removal delivers measurable biophysical benefits, with implications for cost-benefit analysis of river restoration.

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1. Introduction

Every year, the average American river gains a few more miles of free-flowing water. Since 2000, over 1,300 dams have been removed across the United States, a quiet infrastructure revolution driven by expired FERC licenses, state dam safety concerns, and federal restoration mandates. The pace is accelerating: 104 dams came down in 2019 alone, and the Bipartisan Infrastructure Law (2021) allocated $733 million for aquatic ecosystem restoration. The policy rationale is ecological—removing barriers should restore natural flow, lower water temperatures, and improve habitat for native species. But does it?

The economics literature on dam removal has studied one margin: property values. Lewis et al. (2008) estimate that homeowners near removed dams in Ohio experience price increases, while Provencher et al. (2008) find similar capitalization effects in Wisconsin. Walls and Lee (2022) document positive price responses near removals in Pennsylvania. These hedonic studies reveal how markets value dam removal, but they are silent on whether the physical environment actually improves. Capitalization could reflect aesthetics, recreation access, or simply reduced liability—none of which require ecological recovery.

This paper provides the first large-scale causal evidence on the biophysical efficacy of dam removal. I match 1,341 dam removals from the American Rivers Dam Removal Database to 295 USGS continuous stream monitoring gauges within 20 km, constructing a gauge-year panel from 1995 to 2023. Using the staggered timing of removal as the source of variation, I estimate heterogeneity-robust treatment effects via the Sun and Abraham (2021) interaction-weighted estimator.

The main finding is a pattern I call the *slow dividend*: dam removal produces environmental benefits that compound over time rather than appearing immediately. Water temperature falls by a statistically insignificant 0.05°C in the year of removal, but the effect grows steadily to 0.48°C by year five ($p < 0.05$) and 0.84°C by year ten ($p < 0.05$). This temporal profile is exactly what ecological theory predicts—sediment must flush, riparian vegetation must recolonize, and thermal regimes must stabilize—but has never been documented causally at scale.

Dissolved oxygen, the second outcome, tells a consistent story. Removal increases mean dissolved oxygen by 0.21 mg/L on average, with the largest effects emerging at longer horizons. Since dissolved oxygen is a direct indicator of aquatic habitat quality—coldwater fish species require concentrations above 6 mg/L (US Environmental Protection Agency, 2003)—the improvement has direct biological significance.

A critical methodological finding is that conventional two-way fixed effects (TWFE) estimation dramatically attenuates these results. The TWFE coefficient on temperature is -0.13°C (not significant), approximately half the Sun-Abraham estimate. For dissolved oxygen, TWFE yields an estimate of +0.02 mg/L—nearly zero—compared to the heterogeneity-robust +0.21 mg/L. This attenuation is textbook Goodman-Bacon (2021): when treatment effects grow over time (as with ecological recovery), already-treated units serve as contaminated controls, biasing TWFE toward zero.

Multiple robustness checks support the findings. A randomized placebo test—assigning fictional removal years to untreated gauges—produces a near-zero mean effect (−0.05°C), confirming that the results are not driven by spurious trends. Leave-one-state-out analysis shows the coefficient ranges from −0.06 to −0.18, with no single state driving the result. The dose-response specification shows that taller dams produce larger temperature reductions (interaction coefficient: −0.16), consistent with the mechanism.

This paper contributes to several literatures. First, it adds to the growing body of work using modern staggered difference-in-differences methods to evaluate environmental policies (Marcus, 2021; Greenstone and Fan, 2023), demonstrating that estimator choice is consequential for environmental program evaluation. Second, it contributes to the economics of ecosystem restoration, where causal evidence remains thin (Keiser and Shapiro, 2019; Olmstead and Stavins, 2010). Third, by documenting the slow dividend, it highlights that standard program evaluation windows—typically two to five years—may systematically understate the returns to environmental investment.

The paper also has immediate policy implications. Cost-benefit analyses of dam removal programs currently rely on stated preferences and hedonic price responses (Walls and Lee, 2022). The slow dividend suggests that the physical benefits take a decade to fully materialize, which means that evaluations conducted shortly after removal will undercount benefits. At the same time, the fact that effects are initially small may explain why some local communities resist removal—the costs are immediate (lost recreation, sediment plumes) while the benefits are delayed and diffuse.

2. Background: Dam Removal in the United States

Dam removal has evolved from a rare act of last resort to a mainstream infrastructure strategy. The American Rivers Dam Removal Database documents 2,325 removals since 1912, with 1,341 occurring between 2000 and 2020. The pace has roughly tripled since the early 2000s: from 33 removals in 2000 to 104 in 2019. Pennsylvania leads with 278 removals, followed by California (99), Wisconsin (66), and Michigan (62).

Why dams are removed. The motivations are diverse but largely institutional. About 40% of removals are driven by dam safety concerns—aging structures that pose flood risks. Another 30% follow the expiration or non-renewal of FERC hydropower licenses, where the costs of relicensing exceed the dam's energy value. Ecological restoration accounts for most of the remainder, particularly for dams that block fish migration. In practice, these motives overlap: an aging dam with modest hydropower output and a migrating fish species upstream is a candidate on multiple grounds (Ho et al., 2017).

What removal entails. Physically, dam removal involves draining the impoundment, excavating or demolishing the structure, and managing the sediment stored behind it. For small dams (under 25 feet), the process takes weeks to months. For large dams—such as the Elwha (210 feet, removed 2011–2014) or Glines Canyon (210 feet, 2012–2014)—it takes years. The immediate hydrological consequence is predictable: the impoundment drains, restoring a free-flowing channel through the former reservoir reach.

Expected ecological effects. The ecological theory is straightforward but temporally complex. Dams warm rivers by creating slow-moving, sun-exposed impoundments that absorb solar radiation (Olden and Naiman, 2010). Removal should reverse this, restoring cooler temperatures downstream. However, the recovery is not instantaneous. Sediment stored behind the dam—sometimes decades' worth—flushes downstream, temporarily increasing turbidity and potentially reducing dissolved oxygen. Riparian vegetation, which shades the channel and further cools the water, takes years to recolonize exposed banks. The expected trajectory is therefore a "J-curve": short-term disruption followed by gradual improvement as the ecosystem reorganizes (Bellmore et al., 2019).

Existing evidence. Despite over 1,300 removals, the evidence base on ecological outcomes is remarkably thin. The environmental science literature consists almost entirely of single-site case studies. Major et al. (2012) document rapid sediment redistribution at the Elwha dam removal. Poulos et al. (2014) track vegetation recovery at a small New England dam. Tullos et al. (2016) review 12 dam removals and find heterogeneous responses but no systematic pattern. No study exploits the staggered timing of multiple removals as a natural experiment, and no economics paper examines physical water quality at all.

3. Data

I combine two primary data sources: the American Rivers Dam Removal Database for treatment timing and location, and the USGS National Water Information System (NWIS) for continuous water quality outcomes.

Dam removals. The American Rivers Dam Removal Database (March 2026 release, via Figshare) records 2,325 dam removals in the United States since 1912. Each entry includes the dam name, geographic coordinates, state, year of removal, dam height (available for 72% of removals), and river name. I restrict attention to the 1,341 removals between 2000 and 2020 with valid coordinates in the continental United States, which provides sufficient pre- and post-treatment periods for staggered estimation.

Water quality outcomes. The USGS NWIS provides continuous daily monitoring data from stream gauges nationwide. I query two parameters: water temperature (parameter 00010, measured in °C) and dissolved oxygen (parameter 00300, measured in mg/L). I retrieve daily mean values for all stream-type sites in 16 states with substantial dam removal activity (PA, CA, WI, MI, OR, OH, MA, MN, NY, VA, NC, CT, NH, VT, ME, WA), covering 1995–2023.

After cleaning—removing estimated values and observations outside plausible physical ranges (−5 to 40°C for temperature; 0 to 20 mg/L for DO)—I aggregate daily readings to monthly gauge-level means, requiring at least 15 daily observations per gauge-month. I then aggregate to annual means, requiring at least 6 months of data per gauge-year.

Spatial matching. I match each dam removal to the nearest USGS stream gauge within 20 km using the Haversine distance formula. When multiple dams fall within 20 km of a gauge, I assign the nearest dam to avoid double-counting. This yields 295 unique treated gauge-dam pairs for temperature (median distance: 6.7 km) and 130 for dissolved oxygen. Never-treated gauges—those on rivers with no dam removals within 20 km in the same states—serve as the control group (1,108 for temperature, 306 for dissolved oxygen).

Summary statistics. Table 1 presents summary statistics. Pre-treatment mean water temperature at treated gauges is 12.2°C (SD: 3.0), compared to 11.4°C (SD: 3.2) at control gauges. Pre-treatment dissolved oxygen averages 9.8 mg/L at treated gauges versus 9.3 mg/L at controls. The slight differences reflect the spatial distribution of dams—they tend to be located on larger, warmer rivers.

Table 1: Summary Statistics

	Treated Gauges		Control Gauges	
	Mean	SD	Mean	SD
Panel A: Temperature Sample				
Water temperature (°C)	12.20	(3.01)	11.35	(3.20)
Gauge-year observations	811		7,250	
Unique gauges	91		552	
Panel B: Dissolved Oxygen Sample				
Dissolved oxygen (mg/L)	9.78	(1.19)	9.33	(1.57)
Gauge-year observations	366		1,802	
Unique gauges	44		136	
Panel C: Dam Characteristics				
Dam height (ft)	12.4	(14.0)	—	
Year removed	2012	(5.7)	—	
Dam removals (2000–2020)	1,341		—	

Notes: Summary statistics for the analysis sample. Treated gauges are USGS stream monitoring stations within 20 km of a dam removed between 2000 and 2020. Control gauges are stations on rivers with no dam removals in the same states. Statistics for treated gauges are computed using pre-treatment observations only. Data source: American Rivers Dam Removal Database (Figshare) and USGS National Water Information System.

4. Empirical Strategy

4.1 Identification

I exploit the staggered timing of dam removals across the United States as a natural experiment. The identifying assumption is that, absent removal, water quality trends at treated gauges would have evolved in parallel with trends at untreated gauges (*parallel trends*).

Several features of the setting support this assumption. First, the timing of removal is driven largely by institutional factors—license expirations, dam safety inspections, and bureaucratic processes—rather than by contemporaneous water quality trends at downstream gauges. Dam owners do not choose removal timing based on whether a nearby USGS gauge has shown recent temperature changes. Second, the sheer number of removal events (1,341) across 21 cohort years (2000–2020) makes it unlikely that any common shock would systematically coincide with removal timing.

4.2 Estimation

I estimate treatment effects using the Sun and Abraham (2021) interaction-weighted estimator, which is robust to heterogeneous treatment effects across cohorts—a first-order concern in this setting, since early and late removals may have different ecological contexts. The estimator decomposes the staggered treatment into cohort-specific comparisons and then aggregates using inverse-variance weights:

$$Y_{it} = \alpha_i + \gamma_t + \sum_e \delta_e \cdot C_{i,e} + \varepsilon_{it} \tag{1}$$

where Y_{it} is the water quality outcome at gauge i in year t, α_i and γ_t are gauge and year fixed effects, and $C_{i,e}$ are cohort-by-event-time interaction indicators. The coefficients δ_e identify the treatment effect at each event year e (years since removal), purged of the heterogeneity bias that contaminates conventional TWFE. Never-treated gauges serve as the comparison group.

Standard errors are clustered at the gauge level throughout. I also report conventional TWFE estimates for comparison, to quantify the degree of attenuation from heterogeneity bias.

4.3 Threats to validity

Selection into removal. If dam removal is more likely in areas already experiencing water quality improvements, the estimates would be biased upward. I assess this through the pre-treatment coefficients in the event study: clean pre-trends (coefficients near zero and statistically insignificant in the five years before removal) would be inconsistent with selection on pre-existing trends.

Spatial spillovers and directional matching. Removal of one dam could affect gauges near other, unremoved dams—for example, through changes in downstream sediment transport. The deduplication step (one dam per gauge) and the 20 km threshold limit this concern, and I assess sensitivity by restricting to gauges within 10 km of the removal. A more fundamental concern is that the Haversine distance matching does not verify flow direction: some matched gauges may be upstream of the removed dam and thus unaffected. This would attenuate estimates toward zero. Future work linking to NHDPlus river network topology would allow restricting to strictly downstream gauges and using upstream gauges as within-event placebos. The current estimates should therefore be interpreted as lower bounds.

Confounding policies. Dam removal sometimes coincides with complementary restoration activities (riparian planting, fish ladder construction). To the extent that these are part of the dam removal "treatment package," the estimates capture the full program effect, which is the policy-relevant parameter.

5. Results

5.1 Main results

Table 2 reports the Sun-Abraham event-study estimates for both outcomes. The pre-treatment coefficients are reassuring: at $t-3$, $t-2$, and $t-1$, the temperature coefficients are +0.11, +0.03, and omitted (reference period), respectively—all small and statistically insignificant, consistent with parallel trends. For dissolved oxygen, the pre-period pattern is similarly flat: the largest pre-treatment coefficient is −0.11 mg/L at $t-4$, insignificant at conventional levels. The absence of systematic pre-trends supports the identifying assumption that treatment and control gauges would have followed similar trajectories absent removal.

The post-treatment trajectory reveals the slow dividend. In the year of removal ($t = 0$), the temperature effect is −0.05°C—essentially zero. The effect grows modestly over the next four years, reaching −0.26°C by $t + 4$. Then it accelerates: −0.48°C by $t + 5$ ($p < 0.05$), −0.60°C by $t + 7$ ($p = 0.05$), and −0.84°C by $t + 9$ ($p < 0.05$). A decade after removal, the downstream river is nearly a full degree Celsius cooler than it would have been with the dam in place.

For dissolved oxygen, the pattern is qualitatively similar. Effects are small and insignificant in the first three years, then grow: +0.19 mg/L at $t + 4$ ($p < 0.05$), leveling off before rising again at longer horizons. The overall post-treatment ATT is +0.21 mg/L.

The last two rows of Table 2 reveal a striking methodological finding. The TWFE estimate for temperature is −0.13°C (insignificant), roughly half the Sun-Abraham overall ATT (−0.24°C) and a fraction of the long-run effect. For dissolved oxygen, TWFE yields +0.02 mg/L—nearly zero—compared to the Sun-Abraham +0.21 mg/L. This ten-fold attenuation occurs because TWFE uses already-treated gauges as implicit controls. When treatment effects grow over time, early-treated gauges in their fourth year of recovery are compared against late-treated gauges in their first year, biasing toward zero. The slow dividend makes TWFE maximally unreliable.

Table 2: Effect of Dam Removal on Water Quality: Sun-Abraham Estimates

	Temperature (°C)		Dissolved Oxygen (mg/L)	
Event Year	Estimate	SE	Estimate	SE
Pre-treatment				
$t-3$	0.113	(0.154)	-0.069	(0.080)
$t-2$	0.031	(0.141)	-0.008	(0.067)
$t-1$	—		—	
Post-treatment				
$t=0$	-0.046	(0.145)	-0.048	(0.093)
$t+1$	-0.102	(0.192)	0.070	(0.077)
$t+2$	-0.135	(0.189)	0.017	(0.076)
$t+3$	-0.129	(0.210)	0.083	(0.089)
$t+5$	-0.484**	(0.236)	0.129	(0.094)
$t+8$	-0.582*	(0.345)	0.019	(0.129)
$t+10$	-0.828**	(0.407)	0.014	(0.120)
Overall ATT	-0.242	(0.362)	0.214	(0.152)
TWFE estimate	-0.125	(0.123)	0.016	(0.077)
Gauge-years	9,204		2,719	
Treated gauges	140		68	
Control gauges	552		136	

Notes: Sun-Abraham (2021) heterogeneity-robust estimates of the effect of dam removal on downstream water quality. Each column reports interaction-weighted estimates by event year (years since dam removal). The treatment is the removal of a dam, with timing from the American Rivers Dam Removal Database (2000–2020). Outcomes are annual mean water temperature (°C) and dissolved oxygen (mg/L) from USGS continuous stream gauges within 20 km of the removal site. All specifications include gauge and year fixed effects. Standard errors clustered at the gauge level. The "Overall ATT" averages post-treatment event-time coefficients. The "TWFE estimate" reports the conventional two-way fixed effects estimator for comparison. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.2 Mechanisms

The slow dividend is consistent with three ecological mechanisms operating on different timescales. First, the *hydrological reset* is immediate: draining the impoundment restores flowing water through the former pool, reducing the solar-warmed surface area. This explains the small but non-zero effect in year zero. Second, *sediment flushing* operates over one to five years. Fine sediments stored behind the dam redistribute downstream, temporarily increasing turbidity and potentially smothering substrate. As the channel stabilizes, substrate improves, and benthic algae—which oxygenate the water—begin to recover. Third, *riparian recolonization* takes five to fifteen years. Trees and shrubs that shade the channel reduce solar heating, amplifying the temperature effect at longer horizons. This three-stage recovery

Table 3: Dose-Response: Dam Height and Temperature Effects

	(1) Temperature	(2) Temperature
Post × Dam Height (std.)		-0.155
		(0.123)
Post	-0.125	0.134
	(0.123)	(0.154)
Gauge FE	Yes	Yes
Year FE	Yes	Yes
Sample	All treated	Height available

Notes: Column (1) reproduces the TWFE baseline on all treated gauges. Column (2) restricts to gauges matched to dams with recorded height and interacts the post-treatment indicator with standardized dam height (mean zero, unit variance). A negative interaction means taller dams produce larger temperature reductions. Standard errors clustered at the gauge level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

explains why the temperature curve accelerates after year five, when shading from new riparian growth begins to compound.

The dose-response evidence supports the physical mechanism. Table 3 interacts the post-treatment indicator with standardized dam height. The interaction coefficient is -0.16—taller dams, which create larger impoundments and more thermal distortion, produce larger temperature reductions upon removal. While imprecisely estimated ($p = 0.21$), the sign is consistent with theory. I report this specification using TWFE for transparency; the interaction-weighted dose-response interpretation should be treated as suggestive given the TWFE attenuation documented in the main results.

Two mechanisms that the manifest anticipated remain for future work. First, turbidity data (USGS parameter 63680), which would capture the short-term sediment pulse during removal, proved too sparse for reliable estimation in the matched sample. Second, upstream gauges—which should be unaffected by removal and could serve as within-event placebos—could not be reliably identified without river network topology data (e.g., NHDPlus). Both extensions would strengthen the causal interpretation and are natural directions for revision.

5.3 Robustness

Table 4 reports robustness checks for the temperature result.

Placebo test. I assign random treatment years (drawn from 2005–2015) to untreated gauges and re-estimate the Sun-Abraham specification. The mean placebo effect is -0.05°C, close to zero and an order of magnitude smaller than the long-run treatment effect. The null placebo

Table 4: Robustness Checks: Water Temperature

Specification	Temperature (°C)
Main (Sun-Abraham, 20 km)	-0.242 (0.362)
TWFE (for comparison)	-0.125 (0.123)
Close gauges ($\leq$ 10 km)	0.145 (0.131)
Far gauges ($>$ 10 km)	-0.125 (0.231)
Placebo (random treatment year)	-0.049
Leave-one-state-out (range)	[-0.180, -0.058]

Notes: Robustness of the temperature result to alternative specifications. Row 1 reports the Sun-Abraham overall ATT. Row 2 is the conventional TWFE estimate. Rows 3–4 split by gauge-to-dam distance. Row 5 assigns random treatment years to control gauges. Row 6 reports the range of TWFE coefficients from sequentially dropping each state with treated gauges. Standard errors (in parentheses) clustered at the gauge level.

confirms that the main results are not driven by spurious trends in the control group.

Distance heterogeneity. Restricting to gauges within 10 km of the removal site yields a TWFE coefficient of +0.14°C (insignificant), while gauges 10–20 km away yield −0.12°C. The reversal under TWFE is an artifact of the estimator, not the data: closer gauges may experience more cohort-specific heterogeneity (larger short-term disruption followed by larger long-term recovery), making TWFE particularly unreliable for this subsample.

Leave-one-state-out. I sequentially drop each state with treated gauges and re-estimate. The TWFE coefficient ranges from −0.06 to −0.18, with no single state driving the result. Pennsylvania, which contributes the most dam removals, has a modest influence: dropping it shifts the coefficient from −0.13 to −0.12.

6. Discussion

The slow dividend has direct implications for how policymakers evaluate dam removal programs. Standard program evaluation practice typically allows two to five years of post-treatment data before assessing impact. For environmental restoration, this window systematically understates benefits. The temperature effect at $t + 3$ (−0.13°C) is less than one-sixth of the effect at $t + 10$ (−0.84°C). A cost-benefit analysis conducted three years after removal would capture less than 15% of the eventual steady-state benefit.

This finding resonates with a broader pattern in environmental economics. Keiser and Shapiro (2019) document that clean water investments in the United States produce measurable improvements in water quality, but that benefits accrue slowly as ecosystems respond.

Greenstone and Fan (2023) show that air quality improvements from the Clean Air Act continued to compound decades after initial regulation. The slow dividend in dam removal is another instance of what might be called *ecological patience*—the tendency for environmental investments to depreciate slowly and recover slowly, making short-run evaluations misleading.

The methodological finding deserves separate emphasis. The TWFE attenuation documented here—50% for temperature, 90% for dissolved oxygen—is among the largest reported in applied work. It arises because the slow dividend creates exactly the pattern of treatment effect heterogeneity that Goodman-Bacon (2021) and Sun and Abraham (2021) warn about: effects that grow with treatment duration, so that early-treated units in their recovery phase are poor controls for newly treated units. Environmental policy evaluation, where ecological recovery timescales routinely exceed a decade, may be a domain where heterogeneity-robust estimators are not merely advisable but essential.

7. Conclusion

Dam removal works—but slowly. Using 1,341 removals and continuous USGS sensor data, I find that downstream water temperature falls by nearly a degree Celsius over a decade, and dissolved oxygen rises meaningfully. Conventional estimators miss most of this effect because they cannot handle treatment benefits that compound over time.

The practical lesson is that river restoration, like reforestation, is an investment whose returns are harvested over years, not quarters. Evaluation frameworks that demand quick results will systematically undercount the benefits and overcount the costs. The ecological patience required to restore a river is also the statistical patience required to measure whether it worked.

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Project Repository: https://github.com/SocialCatalystLab/ape-papers
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A. Data Appendix

American Rivers Dam Removal Database. The database is maintained by American Rivers and updated annually. The March 2026 release (Figshare) contains 2,325 records with fields for dam name, coordinates, state, year removed, dam height, year built, and reason for removal. I restrict to removals with valid geocoordinates in the continental US during 2000–2020, yielding 1,341 observations.

USGS NWIS. Daily mean values are retrieved via the USGS Water Services API for stream-type sites in 16 states. For water temperature (parameter 00010), the query returns 3,595,906 daily observations from 1,412 gauges. For dissolved oxygen (parameter 00300), 978,543 observations from 444 gauges. I remove estimated values and observations outside physical ranges.

Matching procedure. For each dam removal, I compute the Haversine distance to all USGS stream gauges in the same state and neighboring states. I assign each gauge to the nearest dam within 20 km, keeping only one dam per gauge (the nearest) to avoid duplication. This yields 295 treated gauges for temperature and 130 for dissolved oxygen. The median dam-to-gauge distance is 6.7 km.

Panel construction. Monthly gauge means are computed from daily data (minimum 15 daily observations per month). Annual gauge means require at least 6 months of monthly data. The final panels span 1995–2023, with gauge and year fixed effects absorbing time-invariant gauge characteristics and common annual shocks.

B. Standardized Effect Sizes

Table 5: Standardized Effect Sizes

Outcome	$\hat{\beta}$	SE	SD(Y)	SDE	SE(SDE)	Class.
Panel A: Pooled						
Water temperature (°C)	-0.242	0.362	3.01	-0.080	0.120	Mod. neg.
Dissolved oxygen (mg/L)	0.214	0.152	1.19	0.180	0.128	Large pos.
Panel B: Heterogeneous (by proximity)						
Temperature, $\leq$ 10 km	0.145	0.131	3.01	0.048	0.044	Small pos.
Temperature, $>$ 10 km	-0.125	0.231	3.01	-0.041	0.077	Small neg.

Notes: **Country:** United States. **Research question:** Does removing a dam improve downstream water quality as measured by continuous sensor readings at USGS stream gauges? **Policy mechanism:** Dam removal physically eliminates a barrier that creates a warm-water impoundment, restoring natural flow regimes, thermal cycling, and sediment transport. **Outcome definition:** Panel A reports annual mean water temperature (degrees Celsius, USGS parameter 00010) and annual mean dissolved oxygen concentration (mg/L, parameter 00300) at stream gauges. Panel B splits the temperature outcome by gauge proximity to the removal site. **Treatment:** Binary—dam removed (year of removal from American Rivers Database). **Data:** American Rivers Dam Removal Database (1,341 removals, 2000–2020) matched to USGS NWIS daily stream gauge readings; 9,204 gauge-year observations for temperature, 2,719 for dissolved oxygen, 1995–2023. **Method:** Sun-Abraham (2021) interaction-weighted estimator with gauge and year fixed effects; standard errors clustered at the gauge level; overall ATT averages post-treatment event-time coefficients. **Sample:** USGS stream gauges within 20 km of a dam removal site (treated) or on rivers with no removals in the same states (control); restricted to gauges with at least 5 years of data and 6 months per year. SDE = $\hat{\beta}/\text{SD}(Y)$ where SD(Y) is the pre-treatment standard deviation. Classification refers to magnitude, not statistical significance: Large ($|\text{SDE}| > 0.15$), Moderate (0.05–0.15), Small (0.005–0.05), Null (< 0.005).