The number of dam removals in the United States is expected to increase in the coming years, yet we know little about the social effects of dam removal on local people. Here we assess how two dam removals on a large river in the U.S. state of Maine changed local people’s recreational use and perceptions of the river. We used focus groups and key informant interviews to define stakeholders’ social areas of interest, conducted randomized phone surveys 5 years apart to measure changes in these areas of interest, and utilized a difference-in-differences technique corroborated by key informant interviews to analyze the results. Five years after dam removal, perceptions of water quality, swimming, paddling, fishing, and wildlife viewing increased, and the percentage of people saying the river was part of their family’s life increased. Participation in walking/hiking also increased, but participation in boat fishing decreased, and the frequency of canoeing/kayaking declined. The observed effects were confirmed by ex-post key informant interviews. Additional studies are needed to understand the full range of social effects from dam removals and river restoration activities and to improve our general understanding of the social aspects of ecological restoration activities.

Key words: before-after control-impact, computer-assisted telephone interviewing, difference-in-differences, ecological restoration, perceptions, recreation

Implications for Practice
- The social effects of dam removal and river restoration activities can be measured via phone surveys.
- A panel design for phone surveys can have a high loss to follow up, so a cross-sectional design can be used instead.
- Obtaining a representative age distribution through phone surveys is difficult, especially for younger respondents, so data weighting can be used.
- Using mixed modes such as phone texts, email, and postcards to encourage participation in a single mode such as a phone or online survey may increase survey response rates modestly.

Introduction
Many of the dams in the United States no longer serve their intended purpose, and approximately 1,700 dams have been removed in the United States through 2019, with 75% of these removed in the last two decades (American Rivers 2020). Dam removals can be controversial and divide opinion, and studies that narrow the uncertainties of dam removal outcomes are useful sources of information for those considering a dam removal.

The environmental outcomes of dam removals have been comparatively well studied. The 2020 USGS Dam Removal Science Database contains more than 260 citations on the environmental issues of dam removal (Duda et al. 2020), and Tullos et al. (2016) have identified and summarized the common environmental management concerns from dam removal (Tullos et al. 2016). Studies have also looked at changes in property values after dam removal (Lewis et al. 2008; Provencher et al. 2008; Bohlen & Lewis 2009) and how local politics influences outcomes (Fox et al. 2016; Magilligan et al. 2017; Diessner et al. 2020). The social outcomes from dam removal, however, have been rarely studied. Possible reasons for this include that the social outcomes of dam removal are often of less concern to stakeholders than the ecological and physical outcomes, and methods for measuring social outcomes may not be well known in restoration ecology. The social outcomes from dam removal include changes in river recreation and changes in peoples’ perceptions that influence personal and community connections to the river.

Dam removal and river restoration activities are social processes (Wohl et al. 2015), and developing local community support is critical for generating social capital, political will, and
often, project financing. Public opinion frequently decides the fate of dam removals (Johnson & Graber 2002), and conflicts can arise from different stakeholder valuations of the dam and the functions it provides (Jørgensen & Renöfält 2013). Dam removal decisions can be intensely political and become David-versus-Goliath confrontations of local people against government agencies or environmental organizations (Fox et al. 2016). Local people may have formed attachments to a dam and its impoundment for recreational, aesthetic, and historical reasons, and a dam can be part of a community’s identity (Born et al. 1998). Communities may prefer keeping the dam even when the dam is near the end of its life and the cost to rebuild is high (Keilty et al. 2016). Evaluating the social outcomes from river restoration and dam removals would help inform dam removal debates.

A review of U.S. dam removal research found that fewer than 10% of dam removals had been evaluated, and where evaluations were conducted, most were short (<4 years) and had limited or no preremoval monitoring (Bellmore et al. 2017). On the broader topic of U.S. river restoration, an earlier synthesis found that only 10% of project records indicated any assessment or monitoring (Bernhardt et al. 2005). Among the river restoration projects that did have assessments or monitoring, data were often insufficient or the design was inadequate for rigorous evaluation (Bernhardt et al. 2007). Within the many calls for evidence-based conservation (Pullin & Knight 2009; Cooke et al. 2017) is an identified need for more evaluations of socioeconomic outcomes of ecological restoration projects (Aronson et al. 2010). Specifically, social evaluations of dam removal and river restoration activities are needed to provide more holistic knowledge of the overall effects of dam removal and river restoration activities and help communities better understand possible costs and benefits (Bellmore et al. 2017).

Here we present a case study of a river restoration project that measured social changes due to the removal of two dams. The aim of the study was to assess how river restoration activities changed local people’s recreational use and perceptions of the river.

To our knowledge, this is one of the first studies to measure social outcomes from river restoration activities and one of the first river restoration studies to use a difference-in-differences (DID) estimator.

Methods

Study Area

The study area is the lower Penobscot River in the state of Maine in the United States. This is the ancestral home of the Penobscot Indian Nation who still live primarily in this river basin. Following European settlements in the mid-seventeenth century, large-scale harvesting of Penobscot basin forests began. By 1837, more than 250 sawmills powered by milldams were active along the Penobscot and its tributaries (Foster & Atkins 1869). In 1860, the town of Bangor on the Penobscot was the largest lumber-exporting port in the world (EPA 1980). The first pulp and paper mill appeared in 1882 (EPA 1980). Over time, the Penobscot River became a wastewater drainage system for sawmills, paper mills, and municipalities. By 1964, the Penobscot was one of the most polluted rivers in the United States, with a pollution loading of 1 million pounds per day of biochemical oxygen demand—equivalent to the daily domestic sewage of 5 million people (EPA 1980). The 1972 Clean Water Act provided the regulatory framework for cleaning up rivers like the Penobscot.

In 2004, after centuries of tribal protests and decades of negotiations, a Settlement Accord was reached to restore fish passage on the lower Penobscot. In 2010, after a multi-year effort to build public support and secure funding, the Penobscot River Restoration Trust purchased the Great Works, Veazie, and Howland dams. In 2012, the Great Works dam (20 ft high) was removed, followed by the Veazie dam (30 ft high) in 2013. A nature-like fish bypass around Howland dam was completed in 2016. The fish bypass was completed 2 years before our 5-year social survey and is upstream of the communities assessed in this study. Thus, it is unlikely to have substantively influenced the local social context. The total cost of the project was approximately US$64 million. Hydropower generation in the watershed was maintained by increasing the outputs from three other dams in the river basin.

Ecological monitoring began 3 years before dam removal and has continued. In 2020, fish counts at the now lower-most dam on the mainstem river (Milford) estimated 2 million alewives (river herring) and 11,000 American shad, up from near zero preproject (DMR 2020). On the social monitoring, it took longer than anticipated to get the stakeholders aligned and the funding secured, and the baseline was set in December 2013 several weeks after the second dam removal was completed in November 2013. While not ideal, it was only after the lower Penobscot became free-flowing in November 2013 that the majority of social changes were expected, and the first river recreational season after the dam removals took place after the baseline was set. The social monitoring covered the 23 townships downstream of the river restoration activities (Fig. 1).

Design

We followed a widely used theoretical framework for assessing project impacts that can be summarized as: (1) formulate a theory of change (a causal hypothesis—see Supplement S1); (2) make observations at the baseline and endline on important indicators of key theoretical assumptions and outcomes; (3) consider confounding factors that could explain outcomes (counterfactuals); and (4) corroborate the evidence (Ferraro 2009).

Our design is termed a randomized before-after control-impact (R-BACI) (Christie et al. 2020). It used a randomized selection of survey participants to collect a sample that was statistically similar to the general population so that the results could be generalized to the study population. We included a control group to provide a counterfactual to proxy what would have happened if there had been no intervention. Absent a control group, preexisting trends, such as a statewide increase in river recreation, can bias a before-after comparison in an impact site. Our quantitative measurements were corroborated by
Figure 1. Map of townships in the study.
qualitative interviews of experts to confirm and understand the changes.

Within the R-BACI design, we used a quasi-experimental DID technique that subtracts preintervention differences between control and impact groups from post-intervention differences. DID is a widely used technique in economics (Abadie 2005).

Incorporating stakeholder areas of interest in surveys can help ensure the local relevance of survey results (Jorda-Capdevila & Rodríguez-Labajos 2017). To determine the areas of interest for the survey, we held key informant interviews with 12 project stakeholders and focus group discussions with three community stakeholder groups. Members of the Penobscot River Restoration Trust Board then narrowed the survey topics to recreational river use and connections to the river. “Connections to the river” include local people’s perceptions of factors that influence their interactions with the river (e.g., suitability for boating, fishing, and wildlife viewing), river aesthetics, and the role of the river in their lives (e.g., main association with the river, associations with different river values, its positive or negative contribution to the quality of life). Three external peer reviewers provided suggestions on the draft survey questions and proposed methodology. The data were collected by professional polling firms using computer-assisted telephone interviewing surveys 5 years apart.

Sampling
The sample frame was the 84,468 adults enumerated in the 2010 census of the 23 townships. We used cross-sectional random sampling proportional to population size and representative of age and sex ratios of the project area based on 2010 census data. We aimed for a sample size of 600 respondents based on a sample size calculation that assumed, inter alia, an 80% study power and a 5% significance level (two commonly used values). The baseline phone survey used random digit dialing, and free, prior, and informed consent was obtained orally from participants.

The public’s increased unwillingness to respond to cold calls between the baseline and follow-on surveys reduced response rates to levels that made random digit dialing prohibitively expensive. Thus, we opted to use voter registers to obtain telephone numbers and names in the follow-on survey. The implications of this change are that we drew a sample from an older and more affluent population, which had to be corrected by stronger weighting in the analysis. Stronger weights mean less precise estimators and a reduced ability to find statistically significant results. Stronger weighting also has the potential to introduce bias into the results if weights are based on small numbers of respondents (discussed in the following text).

The baseline survey ran from 15 to 22 December 2013 and obtained the desired sex balance of respondents and a reasonable age distribution before we exhausted our data collection budget with \( n = 523 \) respondents. The 2018/2019 survey also started on 15 December and exhausted the (smaller) sample frame on 3 January 2019. Despite calling each nonresponding number 15 times on different days and at different times, the sample target of 600 interviews was not met, and the respondents included very few younger residents. This led us to purchase a more extensive voter register and focus on households with residents under 35. We also used commercial databases to obtain email addresses of registered younger voters. Email and postcards were sent to younger residents inviting them to participate in the survey. These efforts increased the number of younger residents only modestly. The final sample size was 627 in 2018/2019. In 2013, 258 women and 265 men were interviewed, and in 2018/2019, 326 women and 301 men were interviewed.

To provide the counterfactual, we used statewide control groups. In January 2014, we added six of our Penobscot questions (all our budget would allow) to a cross-sectional, statewide, registered-voter phone survey and did this again in January 2019 in a statewide, mixed-mode phone and online panel survey of registered voters. Screener questions in the control surveys excluded respondents who did not live near a river. Those who lived in one of the counties bordering the lower Penobscot were also excluded. In 2014, we had 407 and in 2019, 497 in the control groups (Supplements S2 and S3).

Analysis
To ensure the survey datasets were demographically representative, we used weighting. In 2013, weights were based on location, age, and sex, and in 2018/2019, we added weights for education and income levels because of the differences observed in respondents selected by random digit dialing versus voter registers. The weights were derived using an iterative proportional fitting module for Stata called IPFWEIGHT (Bergmann 2011). To avoid over-amplifying the importance of a small number of respondents, we merged the 18–24 and 25–29 age groups.

The equation for the DID analysis was as per Albouy (2004):

\[
Y_i = \alpha + \beta T_i + \gamma t_i + \delta (T_i \cdot t_i) + \varepsilon_i
\]

where \( Y_i \) is the outcome for respondent \( i \), \( \alpha \) is the constant, \( T_i \) is a dummy variable indicating whether the observation \( i \) is from the treatment or control group, \( t_i \) is a dummy indicating the time of the observation (baseline/follow-on survey), and \( \varepsilon_i \) is a random unobserved error term. The estimated coefficient of the interaction of the time and treatment dummy variables \( \delta \) is the DID estimator.

For the regression analyses, the dependent variables were the survey variables that were included in both the Penobscot and the control surveys. As these were categorical variables, we used logistic regression primarily. For the variables without control data, we used adjusted Wald tests for the before-after analysis.

The statistical analysis was done in Stata 15.1. All regressions were run using the weighted data with Stata’s survey analysis facilities (“svy” prefix command). No covariates were included in the models as the data of both surveys were weighted to the same 2010 census reference values. (See Supplement S2 for an assessment of the parallel paths assumption critical for the DID technique.)

After the data analysis and reporting, we shared our findings in April–May 2020 with 12 local experts knowledgeable about the Penobscot River recreational use and conducted semi-
structured key informant interviews with these experts. Those interviewed included fisheries scientists, paddlers, government officials, and academics. These interviews helped us confirm and interpret the results.

**Results**

Combining all different types of recreational participation on, in, or along the Penobscot in the 12 months before the survey, we found recreational participation increased from 82% in 2013 to 87% in 2018/2019. Participation in walking/hiking along the river also increased. Participation in boat fishing decreased on the Penobscot compared to the statewide data, and the frequency (but not the participation rate) of canoeing/kayaking declined on the Penobscot. None of the other recreational indicators had statistically significant changes on the Penobscot or when compared to the statewide data (Table 1).

We also asked respondents whether the restoration work had changed their personal use of the river, and 9% said yes (6% in a positive and 2% in a negative way). Water recreation

### Table 1. Recreational results (DID results shown for questions included in the control surveys). CI, confidence interval; ns, nonsignificant.

| Variable                                                                 | Penobscot 2013 | Penobscot 2018/2019 | Difference | 95% CI     | Control 2014 | Control 2019 | DID      | 95% CI     |
|--------------------------------------------------------------------------|----------------|--------------------|------------|------------|--------------|--------------|----------|------------|
| Participation in any form of active recreation                           | 82%            | 87%                | +5%        | 0.2–10%    | –            | –            | –        | –          |
| Presence of the Penobscot added pleasure to land-based recreation         | 83%            | 89%                | +6%        | 0.6–11%    | –            | –            | –        | –          |
| Participation in water-based recreation                                  | 37%            | 38%                | ns         | –          | 53%          | 49%          | ns       | –          |
| Participation: individual activities                                      |                |                    |            |            |              |              |          |            |
| Walking/hiking                                                           | 64%            | 72%                | +8%        | 1–14%      | –            | –            | –        | –          |
| Canoeing/kayaking                                                        | 23%            | 25%                | ns         | –          | 40%          | 33%          | ns       | –          |
| Bank/wader fishing                                                       | 16%            | 19%                | ns         | –          | 27%          | 30%          | ns       | –          |
| Motorboating                                                             | 14%            | 12%                | ns         | –          | 26%          | 28%          | ns       | –          |
| Boat fishing                                                              | 14%            | 10%                | ns         | –          | 22%          | 26%          | –8%–17%  | –          |
| Participation frequency (% who participated >10 times/year)              |                |                    |            |            |              |              |          |            |
| Canoeing/kayaking                                                        | 19%            | 9%                 | −10%       | −2 to 19%  | 23%          | 19%          | ns       | –          |
| Bank/wader fishing                                                       | 26%            | 32%                | ns         | –          | 35%          | 25%          | ns       | –          |
| Motorboating                                                             | 23%            | 14%                | ns         | –          | 32%          | 27%          | ns       | –          |
| Boat fishing                                                              | 20%            | 20%                | ns         | –          | 35%          | 27%          | ns       | –          |

### Table 2. River connection results (DID results shown for questions included in the control surveys). CI, confidence interval; ns, nonsignificant.

| Variable                                                                 | Penobscot 2013 | Penobscot 2018/2019 | Difference | 95% CI     | Control 2014 | Control 2019 | DID      | 95% CI     |
|--------------------------------------------------------------------------|----------------|--------------------|------------|------------|--------------|--------------|----------|------------|
| Penobscot forms part of my family’s life—affirmative answers             | 41%            | 54%                | +13%       | 5–20%      | 49%          | 35%          | +27%     | 15–38%     |
| First thought of the Penobscot is of pollution/need cleaning up          | 16%            | 11%                | −6%        | −1 to 11%  | –            | –            | –        | –          |
| Perceived water quality rated as poor                                   | 28%            | 20%                | −8%        | −2 to 15%  | –            | –            | –        | –          |
| Perceived swimming quality rated as poor to fair                         | 79%            | 71%                | −7%        | −0.3 to 14%| –            | –            | –        | –          |
| Perceived paddling quality rated as very good to excellent              | 33%            | 41%                | +9%        | 0.9–16%    | –            | –            | –        | –          |
| Perceived fishing quality rated as very good to excellent               | 11%            | 19%                | +8%        | 3–14%      | –            | –            | –        | –          |
| Perceived views and appearance rated as good to excellent               | 74%            | 81%                | +7%        | 1–13%      | –            | –            | –        | –          |
| Perceived possibility to see wildlife rated as good to excellent         | 72%            | 78%                | +7%        | 0.2–13%    | 87%          | 84%          | ns       | –          |
| Living near the Penobscot adds to quality of life                        | 78%            | 69%                | +9%        | 3–15%      | –            | –            | –        | –          |
| Most important function of the river is providing wildlife habitat       | 33%            | 40%                | +7%        | 0–14%      | –            | –            | –        | –          |
| Most important function of the river is providing economic opportunities | 12%            | 7%                 | −5%        | −1 to 9%   | –            | –            | –        | –          |
participants were more likely to mention positive changes than respondents who did not participate in that activity, but statistically significant differences were only found for bank and/or wader fishers (16% vs. 4%) and paddlers (14% vs. 4%) and not for motor boaters or boat fishers. Bird and wildlife watchers were also significantly more likely to indicate a positive change than nonparticipants (9% vs. 2%). In contrast, for walking or hiking, picnicking, jogging, or bicycling along the river, we found an almost identical likelihood of noting a positive impact of the restoration work on their river use among participants and nonparticipants.

On connections to the river, when we asked respondents if the river forms part of their family’s life, in 2013, 41% answered yes and in 2018/2019, 54% answered yes. In the statewide surveys, this indicator dropped from 49% in 2013 to 35% in 2018/2019, which was counter to the Penobscot trend. For the question about the possibility of seeing wildlife on the local river, there was a 7% increase in good to excellent ratings for the Penobscot. There were several other changes in connections to the river including perceived increases in fishing quality and paddling quality (Table 2).

We also asked directly whether the dam removal would affect (2013) and had affected (2018/2019) recreational opportunities and people’s connections to the river positively or negatively. For both anticipated and experienced effects, the positive answers outweighed the negative ones by a factor of five. There was no gender difference in these results (Sherren et al. 2017).

**Discussion**

After the river restoration activities, there were positive and negative recreational outcomes. Participation in river walking/hiking increased in the townships, but participation in boat fishing decreased, and the frequency of canoeing/kayaking declined. These effects were corroborated by ex-post interviews with experts knowledgeable about the local context who noted new walking paths along the river, fewer functioning boat ramps on the Penobscot because the water level dropped, and fast-flowing water with exposed rocks in the affected parts of the river that made boat fishing challenging and canoeing/kayaking unsuitable for beginners.

On connections to the river, the increased possibility of seeing wildlife on the river reported by survey respondents was the cause of changes in boat fishing, canoeing/kayaking, and the increased possibility of seeing wildlife on the river. The increase in walking/hiking near the river is more difficult to attribute directly to the restoration activities, as there was a positive trend in walking before the work began, and there were investments in riverside walking paths before and after dam removal. Moreover, walkers were no more likely to indicate a positive impact from restoration activities on their use of the river than nonwalkers.

Including a control group substantially changed our results. In two out of three variables with statewide data, the locally significant changes we observed became nonsignificant when compared to the statewide trend, with the reverse applying to one variable. Including a control group allows one to infer the cause of an observed outcome (Ferraro & Pattanayak 2006).

Given that random digit dialing is no longer viable for phone surveys, an alternative is sampling voter registries as we did. This, however, created the need for increased weighting because registered voters tend to be older and wealthier than the general population (Kennedy & Keeter 2019). For study areas with modest population size—like ours—voter registries can also be problematic, as this approach reduces the size of the sample frame, which together with the low response rates found in phone surveys, can exhaust an available sample frame before a sufficiently large sample is obtained. A common alternative is using mixed-mode surveys, such as combining an online panel and phone survey. However, when sampling from a relatively small area, sufficient online panel participants may not be available. Using mixed modes such as phone texts, email, and postcards to encourage participation in a single mode such as a phone or online survey is another way to avoid missing out on certain demographics (Dillman et al. 2014), although this was only moderately successful in generating responses in our study.

There are several limitations to our results. Our baseline survey began a few weeks after the second dam was removed, and changes could have begun earlier, especially for river perceptions. If this were the case, it would not change our results, but it would mean that our results underestimate the size of the actual change. Weighting survey data reduces the accuracy of estimates and can introduce bias. In 2018/2019, the weights applied were high for those aged 18–29 years because of the small number of respondents we had in this age group. If the 18- to 29-year-olds in the survey were not representative of their peers in the general population, this affects the results. Moreover, the 95% confidence intervals of several of our variables are close to zero, and those results should be treated with caution.

We had control data for only a limited number of indicators and therefore could not use DID analysis on all variables in the survey which makes it harder to prove causality. We sought to compensate for this in part through our ex-post key informant interviews to “ground truth” our quantitative findings. However, we could not ground truth the control results in the same manner.
The large drop in the proportion of statewide control respondents who felt their local river forms part of their family life remains unexplained, which creates uncertainty around this result.

Caution should also be used when generalizing our results to populations outside the lower Penobscot. Population densities in our study area were low and economic uses of the river preintervention were modest. In long-humanized U.S. landscapes such as New England, others have found that dams may be a cherished part of the community, and restoration advocates’ goals may be far removed from those of the community (Fox et al. 2016). Such sentiments are also present in part of the Penobscot communities but were not the dominant view as shown in the surveys.

Of more relevance is the generalizability of our approach to measuring the social effects of dam removal. R-BACI designs and a DID technique provide a cost-effective way to monitor the social effects of the dam removal and measure dam removal outcomes of interest to stakeholders. This social assessment cost US$119,268, which is 0.19% of the total cost of the river restoration project.

Our organization funded this study because of questions from community members about the social outcomes from dam removals. Providing such information helps communities better understand the possible costs and benefits of dam removal.

To our knowledge, this is one of the first studies to measure the social effects of dam removal, but it is only one study from one river. Additional studies are needed to understand the range of social effects from dam removals and river restoration activities and respond to the calls for monitoring the social aspects of ecological restoration activities (Aronson et al. 2010; Martin & Lyons 2018).

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LITERATURE CITED

Abadie A (2005) Semiparametric difference-in-differences estimators. The Review of Economic Studies 72:1–19
Albouy D (2004) Program evaluation and the difference in difference estimator. Economics 131:1–4
American Rivers (2020) Dam removal database. https://figshare.com/articles/dataset/American_Rivers_Dam_Removal_Database/5234068 (accessed Dec 2020)
Aronson J, Blignaut JN, Milton SJ, Le Maitre D, Esler KJ, Limouzin A, Fontaine C, De Wit MP, Mugido W, Prinsloo P (2010) Are socioeconomic benefits of restoration adequately quantified? A meta-analysis of recent papers (2000–2008) in Restoration Ecology and 12 other scientific journals. Restoration Ecology 18:143–154
Bellmore RJ, Duda JJ, Craig LS, Greene SL, Torgersen CE, Collins MJ, Vitum K (2017) Status and trends of dam removal research in the United States. WIREs: Water 4:e1164
Bergmann M (2011) IPFWEIGHT: Stata module to create adjustment weights for surveys. http://EconPapers.repec.org/RePEc:boc:bocode:s457353 (accessed Dec 2020)
Bernhardt ES, Palmer MA, Allan J, Alexander G, Barnas K, Brooks S, Carr J, Clayton S, Dahm C, Pollastad-Shah J (2005) Synthesizing US river restoration efforts. Science 308:636–637
Bernhardt ES, Sudduth EB, Palmer MA, Allan JD, Meyer JL, Alexander G, Pollastad-Shah J, Hassett B, Jenkinson R, Lave R (2007) Restoring rivers one reach at a time: results from a survey of US river restoration practitioners. Restoration Ecology 15:482–493
Bohlen C, Lewis LY (2009) Examining the economic impacts of hydropower dams on property values using GIS. Journal of Environmental Management 90:S258–S269
Born SM, Genskow KD, Filbert TL, Hernandez-Mora N, Keefe ML, White KA (1998) Socioeconomic and institutional dimensions of dam removals: the Wisconsin experience. Environmental Management 22:359–370
Christie AP, Abecasis D, Adjouad M, Alonso JC, Amano T, Anton A, Baldigo BP, Barrientos R, Bicknell JE, Buhi DA (2020) Quantifying and addressing the prevalence and bias of study designs in the environmental and social sciences. Nature Communications 11:1–11
Cooke SJ, Wesc S, Donaldson LA, Wilson AD, Haddaway NR (2017) A call for evidence-based conservation and management of fisheries and aquatic resources. Fisheries 42:143–149
DMR (Department of Marine Resources) (2020) Trap count statistics. Department of Marine Resources, Augusta, Maine. https://www.maine.gov/dmr/science-research/searum/programs/trapcounts.html (accessed Dec 2020)
Diessner NL, Ashcraft CM, Gardner KH, Hamilton LC (2020) I’ll be damned! Public preferences regarding dam removal in New Hampshire. Elementa: Science of the Anthropocene 8:003
Dillman DA, Smyth JD, Christian LM (2014) Internet, phone, mail, and mixed-mode surveys: the tailored design method. John Wiley & Sons, Hoboken, New Jersey
Duda J, Johnson R, Wiefurch D, Wagner E, Bellmore J (2020) USGS Dam Removal Science Database v3.0. https://doi.org/10.5066/P9JEC9G (accessed Apr 2021)
EPA (Environmental Protection Agency) (1980) A water quality success story: Penobscot River, Maine. Environmental Protection Agency, Office of Water Regulations and Standards, Washington D.C.
Ferraro PJ (2009) Counterfactual thinking and impact evaluation in environmental policy. New Directions for Evaluation 2009:75–84
Ferraro PJ, Pattanayak SK (2006) Money for nothing? A call for empirical evaluation of biodiversity conservation investments. PLoS Biology 4:e105
Foster N, Atkins C (1869) Second report of the Commissioners of Fisheries of the state of Maine 1868. Owen and Nash, Printers to the State, Augusta, Maine
Fox CA, Magilligan FJ, Sneddon CS (2016) “You kill the dam, you are a killing a part of me”: dam removal and the environmental politics of river restoration. Geoforum 70:93–104
Johnson SE, Graber BE (2002) Enlisting the social sciences in decisions about dam removal. Bioscience 52:731–738
Jorda-Capdevila D, Rodríguez-Labajos B (2017) Socioeconomic value(s) of restoring environmental flows: systematic review and guidance for assessment. River Research and Applications 33:305–320
Jørgensen D, Renöfält BM (2013) Damned if you do, dammed if you don’t: debates on dam removal in the Swedish media. Ecology and Society 18:1
Keilty K, Beckley TM, Sherren K (2016) Baselines of acceptability and generational change on the Mactaquac hydroelectric dam headpond (New Brunswick, Canada). Geoforum 75:234–248
Kennedy C, Keeter S (2019) Why public opinion polls don’t include the same number of Republicans and Democrats. https://www.pollingreport. org/fact-tank/2019/10/25/why-public-opinion-polls-dont-include-the- same-number-of-republicans-and-democrats/ (accessed Apr 2021)
Social changes from river restoration

Lewis LY, Bohlen C, Wilson S (2008) Dams, dam removal, and river restoration: a hedonic property value analysis. Contemporary Economic Policy 26: 175–186

Magilligan F, Sneddon C, Fox C (2017) The social, historical, and institutional contingencies of dam removal. Environmental Management 59:982–994

Martin DM, Lyons JE (2018) Monitoring the social benefits of ecological restoration. Restoration Ecology 26:1045–1050

Petursdóttir T, Arnalds O, Baker S, Montanarella L, Aradóttir ÁL (2013) A social-ecological system approach to analyze stakeholders’ interactions within a large-scale rangeland restoration program. Ecology and Society 18:29

Provencher B, Sarakinos H, Meyer T (2008) Does small dam removal affect local property values? An empirical analysis. Contemporary Economic Policy 26:187–197

Pullin AS, Knight TM (2009) Doing more good than harm—building an evidence-base for conservation and environmental management. Biological Conservation 142:931–934

Sherren K, Beckley T, Greenland-Smith S, Comeau L (2017) How provincial and local discourses aligned against the prospect of dam removal in New Brunswick, Canada. Water Alternatives 10:697

Tullos DD, Collins MJ, Bellmore JR, Bountry JA, Connolly PJ, Shafroth PB, Wilcox AC (2016) Synthesis of common management concerns associated with dam removal. Journal of the American Water Resources Association 52:1179–1206

Wohl E, Lane SN, Wilcox AC (2015) The science and practice of river restoration. Water Resources Research 51:5974–5997

Supporting Information
The following information may be found in the online version of this article:

Supplement S1. Theory of change and representativeness of sample.
Supplement S2. Difference-in-differences technique, parallel paths, and datasets.
Supplement S3. Penobscot and statewide questionnaires.