



Damming news: Geospatial media discourse analysis of dams

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Abstract

Dams are a globally important social-ecological issue, and the practice of removing aging or obsolete dams is increasing in many countries where rivers have been used to fuel industrial growth. News media play an important role in providing information and raising awareness about dam-related decision making and patterns in news media coverage can shape public sense-making about potentially controversial dam decisions. This research focuses on spatial patterns of news media references to “dam removal” georeferenced to a New England dams database, the types of dam removal characteristics that contribute to newsworthiness, and specific media framing strategies. We develop a method, known as DAMMDA, that combines a large geodatabase of dam features and corpus of news media articles. We find that spatial patterns of “dam removal” news media coverage do not necessarily coincide with the actual occurrence of removed dams, nor the distribution of extant dams, in the landscape. Instead, a minority of dams with specific characteristics make up the majority of dam media references. Such “newsworthy dams” are capable of generating hydroelectricity, are situated on large rivers, are located in urban areas, or have already been removed. Further, references to newsworthy dams are often used to frame discussions about future dam decisions in other locations in New England and across the United States. We conclude by reflecting on how this approach is relevant for understanding complex and interconnected factors that can shape controversial sustainability issues, such as the relationships between news media and social-ecological characteristics of infrastructures within landscapes.

Keywords Dam decisions · Geospatial analysis · Media discourse analysis · DAMMDA methodology · Newsworthiness

Introduction

Dams are pervasive anthropogenic features in landscapes, found on nearly every waterway in industrialized countries and serving as the focal point for a range of perspectives

about the relative value of rivers (Altinbilek 2002). Like many other anthropogenic features, dams are situated within complex social-ecological systems. For centuries dams have provided access to fresh water and power for social and industrial purposes (Yüksel 2009). In some areas, dams can help mitigate flood risk, create lentic habitat behind impoundments, and store sediment and legacy contamination. However, global dam construction often negatively impacts the sovereignty and cultural identity of Indigenous peoples (Gosnell and Kelly 2010). Dams are also responsible for significantly reducing freshwater connectivity, with major negative impacts for many native species, particularly sea-run fish (Limburg and Waldman 2009; Hall et al. 2011, 2012; Martin and Apse 2011). Further, dam infrastructure in the United States (U.S.) is aging and removal is becoming an increasingly common practice to reduce safety risks and costs (Born et al. 1998; Doyle et al. 2000; Pohl 2002; Pisaniello et al. 2012) and to restore the ecological benefits of free-flowing rivers (Bednarek 2001; Trinko Lake et al. 2012; Magilligan et al. 2016; Watson et al. 2018; Roy et al. 2018; Dias et al. 2019). Where dams were built to

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support mill industries, giving rise to towns, some communities draw a sense of place and aesthetic value from these structures. These different perspectives related to dams and river restoration can lead to conflict and uncertainty in decision making about them (Lejon et al. 2009; Fox et al. 2016, 2017; Brummer et al. 2017; Magilligan et al. 2017).

Considering the diverse perspectives about dams, there is a pressing need to attend to factors that influence how people gain access to and make sense of information about dams (Lundberg et al. 2017; Diessner et al. 2020), regional dam removal histories (O'Connor et al. 2015; Magilligan et al. 2017), and the tradeoffs of alternative dam decisions (Roy et al. 2018, 2020). Dam removal decisions are often contentious and require careful assessment of social, environmental, and financial trade-offs from options including removing, retrofitting, changing dam management, or maintaining status quo (Born et al. 1998; Fox et al. 2016; Brummer et al. 2017; Roy et al. 2018; Song et al. 2019). News media play an important role in providing information about controversial natural resource decisions, including how journalists frame dam-related options and tradeoffs. News media can influence access to information and help define the available meanings for how people make sense of decisions about complex social-ecological issues (Jørgensen and Renöfält 2013; Feldpausch-Parker et al. 2015; Lundberg et al. 2017).

This study combines a focus on dam removal news media (online news articles) and geospatial information about dam characteristics to provide a method and set of insights about relationships between media coverage and decision making about dams. We start by introducing literature on news media analyses of complex social-ecological issues, building from the limited number of previous studies that have brought together news media and geospatial analysis to highlight the value for understanding perspectives about dams. We then describe our integrated dam and media discourse analysis, a method we refer to as DAMMDA (pronounced “dam-dah”), that combines two large corpus datasets of news media articles and dam characteristics across New England. Intensive and ongoing colonial settlement patterns over the last three centuries have resulted in construction and modification of at least 14,000 dams in this region (Magilligan et al. 2016). Our results show that spatial patterns of media coverage do not match spatial patterns of dam removals or extant dams. This mismatch is in part related to how some dam characteristics appear to be deemed more newsworthy than others. Further, we find that current decisions about dams are framed through previous decisions, especially removals. We conclude by discussing how this method and these results have implications for dams and related complex natural resource decision making issues where understanding the

relationship between news media coverage and geospatial characteristics can provide perspectives about important factors that shape public sense making. All references to dams and removals are in the context of dam removal news media coverage, unless otherwise stated.

Media discourses and social-ecological systems

The term “media discourse” refers to the complex ways in which news media construct, frame, organize, and share information about a topic (Fairclough 1995). As Hansen (2019) describes, media provide a:

reservoir of images, meanings and definitions, on which different publics will draw for the purpose of articulating, making sense of, and understanding environmental problems and the politics of environmental issues. Environmental issues don't simply present themselves as issues for public and political concern. Environmental issues – and public concern about the environment – are socially constructed. (pp. 181–182)

Journalists often rely on framing techniques to describe complex issues in accessible and relatable terms, drawing attention to newsworthy aspects of a topic to the exclusion of other details (Nisbet 2009). News media framing, and especially the construction of “newsworthiness,” holds an important agenda-setting power, where news coverage helps define what audiences learn about and then focus on (Schulz 1982; Rogers et al. 1993; Ader 1995; Griffin and Dunwoody 1997; Fico and Freedman 2001; Wakefield and Elliott 2003; Sampei and Aoyagi-Usui 2009; Hansen 2011; Suldovsky et al. 2018). In their media analysis of arguments about dam removal in Sweden, Jørgensen and Renöfält (2013) identified a host of frames that shaped debates, including the extent to which dam removal would improve fish passage, regulate flow, provide cultural value such as for recreation/aesthetics, and economic issues such as maintenance costs. de Loë (1999) identified a link between the frequency of news coverage and levels of public interest for dam projects in Canada. These frames become recognizable schema through which dam options are negotiated and where other potential frames are not emphasized (Feldpausch-Parker et al. 2013, 2015; Fischlein et al. 2014; Fox et al. 2016, 2017; Lundberg et al. 2017).

How can a focus on news media, with its broad spatial-temporal extent, help identify patterns in perspectives and decision making about these issues across scales? While traditional media studies provide extensive data about perceptions of social-ecological issues, there remains a need to

pair studies of media with studies of geographic patterns, as this pairing can provide ways of making sense of possible relationships between media discourse, ecological conditions, and decision-making patterns (Carvalho 2010; van Zanten et al. 2016; Dodge 2018; Poole 2018; Duffy et al. 2020). There is a limited number of studies that consider this relationship broadly and, as far as we know, none that focus on dams. Poole (2018) studies debates about the siting of a copper mine by combining news articles, corpus linguistics, and GIS analyses to highlight the value and need to further develop “annotation schema to enable different types of ecolinguistics analyses while also integrating GIS techniques for the spatialization and visualization of features” (p. 538). Mahabir et al. (2018) show how combining news media with crowdsourced georeferenced data can help identify factors that shape collective action. Focusing on the contentious issue of aquaculture siting, Duffy et al. (2020) combine news media and a visual geospatial analysis to identify the distinct spatial variation in how news coverage emphasizes risks and/or benefits, highlighting implications of these respective frames for decision making. Together, these studies demonstrate how news articles provide a widely available source of information with broad geographic range and one that has significant potential for contextualizing dam decision making.

Georeferenced news media can provide a spatial context for understanding patterns in debates about dam removal across a landscape, expanding abilities to compare decision making at multiple scales and locations (Dodge 2018). Combining news media data with dam use and characteristics data can improve understanding of conditions that promote dam removal or alternative decisions. In other words, some dams may have social-ecological characteristics that make the prospect of removal more newsworthy. Previous studies on dam removal have identified several characteristics that influence such decisions, including hazardous infrastructure, costly repairs, significant environmental impacts, and inefficient management practices (Born et al. 1998; Doyle et al. 2000; Magilligan et al. 2017). Further, high profile dam removals that are seen as particularly newsworthy can be used to frame present or future decisions and can play an important role in defining the agenda for dam decision making (de Loë 1999).

Thus, combining news media and geospatial datasets can provide important contextual detail about information that is circulating about dams and how that information compares with relevant landscape and dam-related characteristics. Because news articles work to inform readers about the details of dam removal decisions, tracking the frequency of media references to specific dams, combined with data about the characteristics of these dams and their geolocations, may help identify possible influential factors of public sense making and conflict. It is important to note that news

references to “dam removal” are not necessarily confirmation that a dam has been removed, alluding to the prolonged and contentious nature of dam decisions outlined above. Articles may use “dam removal” to refer to dams that may be removed in the future, or that dam removal is one of several alternative options considered, or that the journalist is drawing comparisons between removed and extant dams, or any number of other contexts equally worthy of verification as dam removal itself.

The potential for combining news media and geospatial data to inform dam decision making thus raises three primary research questions:

RQ1. What are the spatial patterns in news media discourse about New England dams and how do these compare with patterns of dams and dam removal?

RQ2. What social-ecological characteristics of dams are prominent in news media and what makes these characteristics newsworthy?

RQ3. To what extent are past dam removal projects referenced in media articles to frame new or future dam removal projects?

Methods

Integrated Dam and Media Discourse Analyses (DAMMDA)

The DAMMDA method provides a conceptual and analytic approach for spatially characterizing news media focused on dam removal, identifying specific dams that dominate news coverage and their social-ecological characteristics and the framing of dam removal projects based on past decisions. DAMMDA comprises a comprehensive inventory of more than 7000 New England dams and a corpus of 1480 digital news articles from U.S. national and regional newspapers. DAMMDA is based on a process of building the respective databases, linking news articles to dam locations, validating linkages between these data, and visualizing and interpreting results. We provide more extensive documentation of the steps for creating the news media database, validating integration techniques, and guidance on how to access and use the original data (University of New Hampshire Data Discovery Center: <https://ddc-nedams.sr.unh.edu>) in the Supplemental Materials. The process for building the geospatial database has been described elsewhere (Gold et al. 2016; Roy et al. 2018). In this section, we focus on steps to integrate news and geospatial databases including how to (1) build a news database; (2) link and validate relationships between news articles and dam locations; (3) use heat maps

to illustrate spatial trends in the prevalence of dam media coverage; (4) conduct mixed methods (quantitative and qualitative) interpretations to identify social-ecological characteristics of newsworthy dams; and (5) deploy network analyses to show links between contemporary dam media references and previous removal projects.

Building and validating a news database

We built a database of online news articles that reference dams that have been removed, are slated for removal, underwent modifications such as fish passage installations, or remain extant. We searched within LexisNexis and Proquest news databases for articles spanning local to nationwide readership, from New England and select U.S. national newspapers, including from regional sources such as *Worcester Telegram & Gazette*, *Providence Journal*, *Lewiston Sun Journal*, *Portland Press Herald*, *Keene Sentinel* and national sources such *L.A. Times*, *New York Times*, *Washington Post*, and *Boston Globe*. We sought to identify news articles describing decisions about dams as opposed to a broader set of news stories about the presence and operation of dams. To help identify relevant articles, we intentionally used the phrases “dam removal” or “remove dam” for this search. Though there were limitations in using “removal” as a modifying phrase on dams, these terms allowed us to narrow the search to a more relevant and manageable set of articles with no need to process excess content irrelevant to dam decision topics.

We used an event-based sampling strategy (Hansen and Machin 2019) to constrain the search to reporting from April 2, 1985 (when the Electric Consumers Protection Act was introduced to the U.S. Congress) to July 2016 (when significant objectives for the Penobscot River Restoration Project were completed). We compiled a database with the headlines and text of returned articles as well as the publication date, newspaper, publishing region, author, and summaries of article content. We removed all duplicate articles which resulted in a final dataset of 1480 articles. To help set up the integration of the news database and geospatial dam data, we first identified dams mentioned in news article text through manual and automated identification based on keyword search. These efforts informed each other over time and allowed us to address the limitations of each distinct method through successive refinements (see Supplemental Materials).

Linking and validating relationships between news and dams

We developed a process (Fig. 1) to link news articles to dam locations in DAMMDA and validate results. We imported

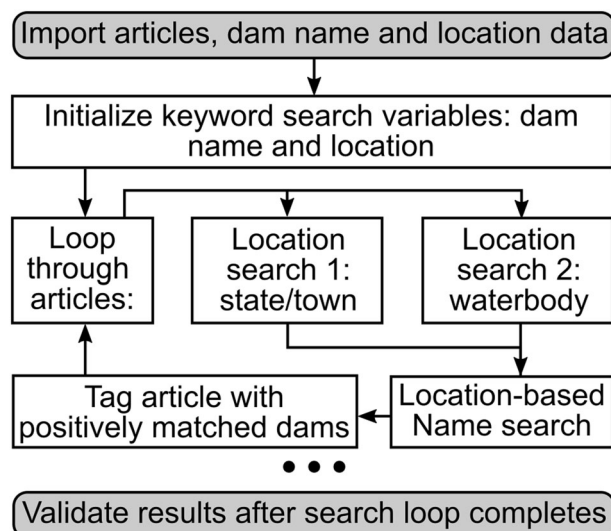


Fig. 1 DAMMDA flowchart for linking and validating media references to dams in geodatabase. Validation occurs after completion of the search loop

text from the news article corpus and name, state, town, and waterbody data for dams into the geodatabase. Dam data were then used as keyword search variables for identifying positive matches in each article. Keyword searches were used to determine instances where database keywords exactly matched words or phrases in each article and these matches formed the basis for linking articles to the dams database. To minimize error, we developed a series of nested keyword searches. We began the process by completing a location search for each article in the corpus, consisting of two independent approaches focused on state/town and waterbody keyword matches (Duffy et al. 2020). Location keywords were a necessary addition to further narrow the search for dam names in each article to avoid erroneous selection of similarly-named dams in multiple locations. The state/town search first identified states listed in the article, then town names for each state. This two-stage approach took advantage of location names listed in articles, such as in the dateline, while avoiding cases where multiple states have identical town names. The waterbody search occurred independently of the state/town search and was used to match dams located in rivers or streams referenced in articles. Our waterbody terms, including stream, river, and pond names, originated from the National Hydrography Dataset (USGS 2019). Both location searches produced a refined list of potential dam matches that were then used as a basis for automated dam name search. Please see Supplemental Materials for additional details on the process of validating the dam names and locations.

To validate our automated dam identification results, we used a process of manual dam identification where we read through a sample of media articles to identify references to

specific dams listed in the New England Dams Database (NEST 2017). First, we created a random sample by generating a random number table to select a 10% of the corpus, resulting in a sample of 148 articles. We used term summarization and frequency reports to verify that the content of the samples did not vary substantially from that of the full dataset.

Teams of two then read through each article in the sample, marking each location in the text where a dam was mentioned and sorting into two categories: direct and indirect mentions. Direct mentions included instances where dams were named specifically (e.g. “the Mill Pond Dam in Durham, New Hampshire”), whereas indirect mentions included instances where dams were not named, yet were referred to in a general way (e.g. “a dam on the Merrimack River in New Hampshire”). For each dam mentioned, the two readers looked up the respective dam in the dams database and noted the dam’s unique identifier in a document listing all dams mentioned per article. Readers reviewed a subset of the 148 sampled articles to compare results and establish inter-coder agreement (Campbell et al. 2013). These separate lists were combined into a single list containing all mentioned dams per article with inconsistencies resolved. In the next phase, each reader examined half of the remaining articles, following a refined version of the above process. After all articles were examined and dam locations identified, one of the authors reviewed the readers’ lists, searched for ambiguous dams using satellite imagery, resolved remaining inconsistencies along with explanatory notes, and synthesized the results in a spreadsheet storing dam identifiers pertaining to each article. This spreadsheet was then used as the baseline to gauge the results of the second complementary method used to identify dams across our entire corpus.

To validate the location search accuracy, we used the sampled set of articles to compare results between the two searches. Taking the list of dams found per article in the manual dam identification process as our baseline, we inspected the list of dams found in each article by the location search and identified the overall number of false positives (dams returned in the location search that had not been returned in the manual search) and false negatives (dams returned in the manual search that had not been returned in the location search) per article. This allowed us to pinpoint anomalies in the baseline dam identification, as the false positives directed our focus to areas of interpretive ambiguity or error that we could address and correct. After several rounds of refinement, our final DAMMDA link validation found 14 dams with false negatives and 7 dams with false positives among 160 dams manually identified within a 148-article sample. Our location search therefore had a failure rate of 3.3% for false negatives and 4.4% for false positives relative to the total number of manually

identified dams for an average model accuracy of 96%. After validating the DAMMDA link, we turned to our integrated analyses using heatmaps, mixed methods techniques, and network analysis.

Heatmaps of media coverage about dams

Heatmaps, also known as kernel density maps, are useful for our objective of identifying spatial patterns in samples of point-based features and instances (Gregory and Hardie 2011; van Zanten et al. 2016; Duffy et al. 2020). We used the kernel density tool in ArcGIS to calculate magnitude-per-unit area from dam point features projected in the North American Datum 1983 Universal Transverse Mercator zone 19 north coordinate system. We used a kernel with search radius of 25 km to generate a heatmap with 1 km resolution. Each dam was counted uniformly without use of weights. We mapped media reference density using the same approach, but instead used the total number of media references summed for each dam as weights for the density calculation. This approach produced maps that indicate greater density for a greater number of media references for a dam or group of dams clustered together. However, the number of dam references varies substantially by state. In order to track the relative distribution of media references within each state without potential bias from occurrences in other states, we standardized media references using a modified *z-score* calculation for each dam reference, $z\text{-score} = (x_i - x_m)/IQR$, where x_i is the number of media references at dam i , x_m is the median number of references per dam in state m where dam i is located, and *IQR* is the interquartile range of media references in the state.

We calculated the centroid, or geometric center, of dam point data to simplify our interpretation of the spatial distribution of dams, dam removals, and media references. Centroids were calculated by taking the mean of individual dam point coordinates for each grouping. Our groupings include extant dams, removed dams, total references, and standardized references. We weighed the averaging for total and standardized news media centroids based on counts (see Supplemental Materials).

Identifying characteristics of newsworthy dams and dam removals

We used mixed methods techniques combining qualitative and quantitative approaches (Creswell 2014; Hansen and Machin 2019) to identify specific characteristics of newsworthy dams using metrics from the dams geodatabase (NEST 2017). We extracted data for dams that are positively matched in articles, including whether the dam had

been removed (NEST 2017), generates hydropower (FERC 2019), contains a pond reservoir (NEST 2017), is located in an urban place (USDA 2019), or is located on a large mainstem river (Olivero and Anderson 2008; USGS 2019). Though the historic record of dam removals in New England is incomplete, removals that have occurred within the time frame of our analysis are well documented (American Rivers 2019), validated by DAMMDA, and noted in the dams geodatabase (NEST 2017). We also used hydropower licensing (FERC 2019) and national waterbody data (USGS 2019) to determine the presence of pond reservoirs behind dams or formerly behind removed dams (Roy et al. 2018). We define large mainstem dams located on rivers with Strahler stream order greater than four (Strahler 1957). Finally, we also reported dams with fish passage facilities currently installed or installed prior to dam removal (NEST 2017). We then calculated relative frequencies of dams with these characteristics and compared these with relative frequencies of media references to dams with these characteristics, to assess if these are over- or under-represented in media coverage relative to their actual occurrence. We selected approximately 300 news articles, including articles used for manual validation of DAMMDA, covering different dam removal or alternative dam decision projects in New England and identified quotes that helped contextualize and enrich our analysis.

Network analysis for linking dam media references

Our manual DAMMDA validation process indicated a trend where references to previously removed dams are often paired with ongoing dam removal projects in a single article to frame dam removal. We refer to these instances as “article coincident references,” representing the total number of references to other dams that coincide within a single article. This metric is useful for understanding the potential impact of newsworthy dams for socially constructing a sense of dams over broader regions (Hansen 2019). We generated a network map representing the total number of references and the number of references coincident with other dams occurring in each article. These data provide measures of the prevalence of individual dams in media coverage and information on how newsworthy dams are used to frame other dam removal projects. Combined with our geospatial component, this analysis also provides information on the spatial range over which newsworthy dams could influence conversations about dam removals. Our network maps were constructed from the results of our DAMMDA link method, with visualizations constructed in Gephi (<https://gephi.org/>). Due to significant regional and national focus on several recent dam removals in Maine

(Opperman et al. 2011), plus the challenge of standardizing article coincident references that cross multiple state boundaries, we chose to focus the network analysis on broader impacts of Maine dams using coincident references calculated from the non-standardized results.

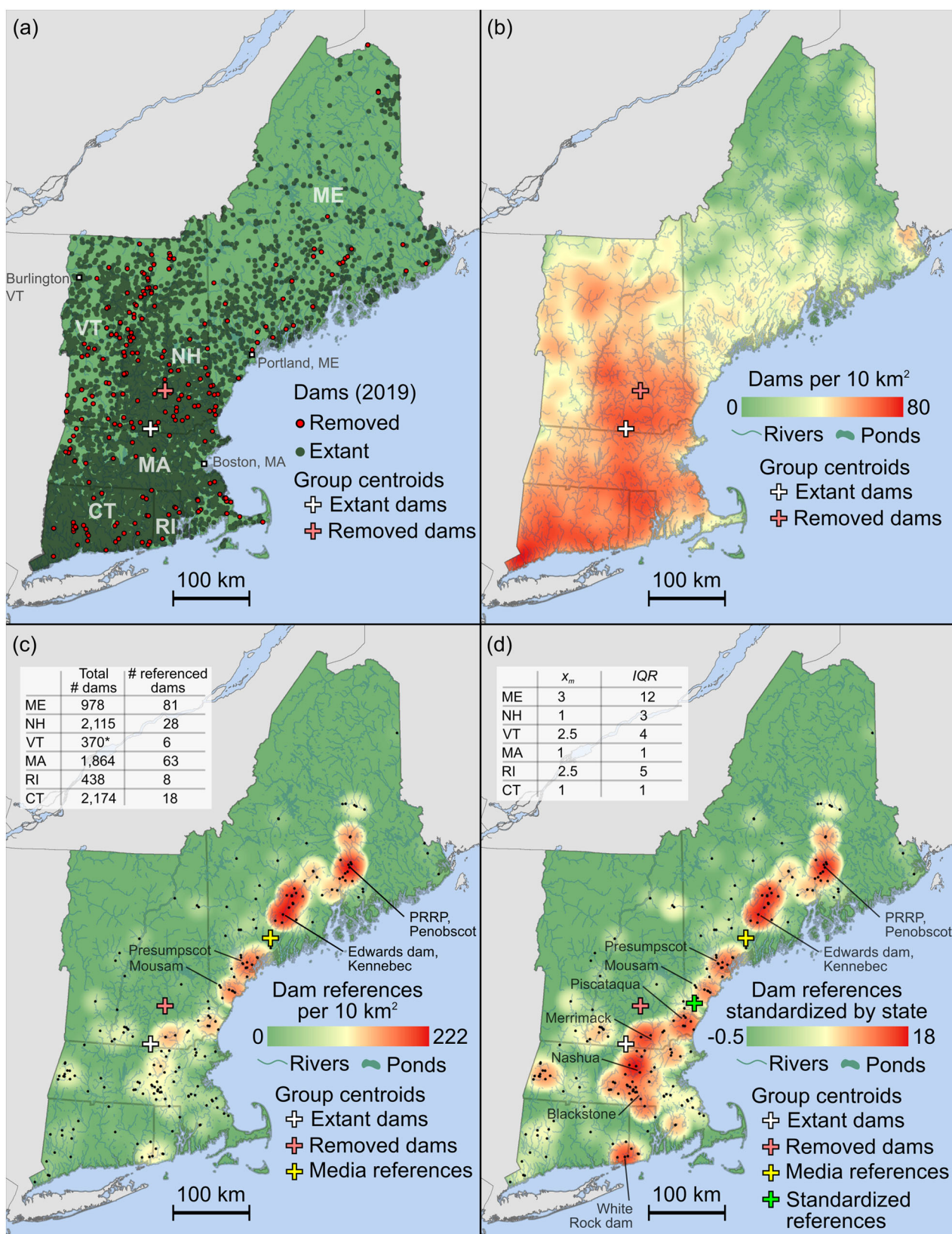
Results and discussion

In this section we return to our guiding research questions focused on spatial patterns evident in news media and dam removals, characteristics of dams that are featured in news articles and their relative newsworthiness, and the extent to which past dam removals shape current news articles about dams. Our analyses demonstrate several key findings: the spatial pattern of dam removal media coverage does not reflect the spatial pattern of dam abundance or even dam removals; specific characteristics present in a minority of dams are over-represented in news media; and it is common practice for news articles to frame new dam decisions based on past dam removals.

Spatial patterns of dams, dam removal, and media coverage (RQ1)

Overall, the spatial pattern of documented dam removals does not correlate with the pattern of dam abundance (Fig. 2a). For example, dams are far more abundant in southern New England (Fig. 2b), while dam removal patterns are generally sporadic with some local clustering. Overall, the centroid of dams in New England occurs along the border of New Hampshire and Massachusetts, while the centroid of removed dams is located 54 km further north in New Hampshire (Fig. 2a) indicating that a relatively larger portion of dams have been removed in northern New England. This pattern occurs despite the greater proportion of dams in southern New England, indicating that dam removal trends do not necessarily reflect the local abundance of dams available for removal. Therefore, there may be local dam, stream, or river attributes that make some dams more eligible for removal or lead to greater coverage in dam removal news media.

Further, the spatial pattern of non-standardized dam media references does not correlate with the pattern of extant dam abundance nor the pattern of removed dams (Fig. 2b, c). However, we note a statistically significant, moderate point-biserial correlation ($\rho = 0.44$, p value = 2×10^{-11}) between the occurrence of dam removal and the abundance of total references, suggesting that frequent media references have a significant association with dam removals. Most dam media references occur in Maine, the state with the lowest density of dams (Fig. 2b). Most of these references link to Edwards Dam, the Penobscot River



◀ **Fig. 2** **a** Map of removed and extant dams in New England, dam point data republished from (NEST 2017) under a CC BY license, with permission from the Data Discovery Center, original copyright 2016. **b** heatmap indicating number of dams per 10 km² area. Dam density increases southward. **c** heatmap of raw dam media references. Black points represent dams referenced at least once by media articles. Several dams in Maine host a significantly greater number of references than other regions. **d** Heatmap of dam media references standardized by state values

Restoration Project dams, and dams along the Presumpscot and Mousam rivers. The centroid for total references occurs 212 km northeast of the centroid for extant dams. An emphasis on coastal dams is also apparent in the news database, as most media references involve dams within 60 km of the coast. This coastal trend contrasts with the general distributions of extant and removed dams. An apparent southwest-northeast linear trend connects dam media references from south-central Massachusetts to central Maine. This trend coincides closely with the Fall Line (Renner 1927), a coastwide change in river gradient providing significant water energy potential close to coastal ports, and therefore has historically been a significant focus of dam construction, community development, and dense population centers (Hunter 1979).

Much like the spatial trend seen in non-standardized references, the standardized references exhibit a linear northeast-southwest pattern, though it is more pronounced with greater representation of dams outside of Maine due to smaller median values and inter-quartile ranges in those states (Fig. 2d). Like total references, standardized references have a significant association with dam removal ($r_{pb} = 0.46$, p value = 1×10^{-13}). In other words, media interest in dam removals is more focused along this linear spatial trend in all states, but dam removals are distributed not just along the linear trend but across all New England. Massachusetts and New Hampshire show particularly stronger media representation along the Merrimack, Nashua, northern Blackstone, and Piscataqua rivers. As before, there is a southwest-northeast linear trend connecting standardized dam media references. The Pawcatuck River's White Rock Dam, located on the coastal edge of the Connecticut-Rhode Island border, is a notable exception. The centroid of standardized references occurs near the southern border of Maine and New Hampshire but is still 105 km from the centroid for extant dams. This suggests that the distribution of standardized media references do not strongly correlate with the distribution of extant dams in New England. These results indicate that the distribution of news media coverage focused on dams does not correlate with the distribution of extant dams or removed dams in New England and that there are additional dam characteristics that influence media coverage.

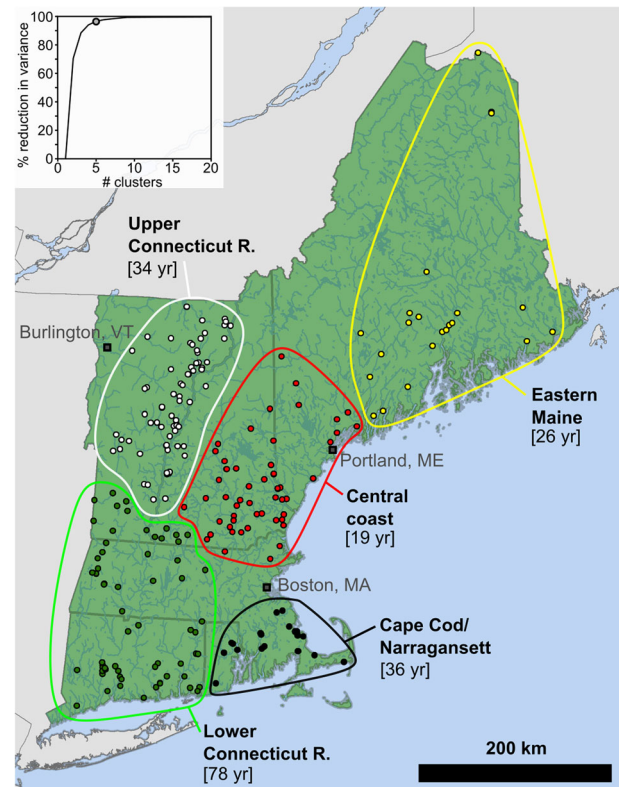


Fig. 3 Dam removal clusters. Number of clusters selected by optimizing reduction in inter-cluster variance, minimizing number of clusters. Years in brackets represent the time range of dam removals in each cluster. Broad distributions and large time intervals suggest that clustered dam removals are rarely coordinated. Total within-cluster variance is 157.4°; mean within-cluster variance is 0.46°. Dam point data republished from (NEST 2017) under a CC BY license, with permission from the Data Discovery Center, original copyright 2016

Further, we selected five spatial cluster groups of removed dams using k-means clustering (Fig. 3). Five cluster groups were used to minimize the total number of clusters and improve the interpretability of results while maintaining a reduction in within-cluster variance greater than 95% relative to the total sample of removed dams. Results indicate several distinct geographic and temporal patterns to dam removal, including upper and lower Connecticut River segments; Cape Cod and Narragansett Bay watersheds; central coast, spanning northern Massachusetts to southern Maine; and eastern Maine. These spatial patterns and timeframes indicate relative challenges of coordinating multiple dam removal decisions at regional or watershed scales (Day 2006; Bernhardt et al. 2007; Crane 2009; Opperman et al. 2011; Roy et al. 2018) and the typically lengthy processes of decision making for each dam removal project (Lejon et al. 2009; Fox et al. 2016; Brummer et al. 2017; Noda et al. 2018). Our discussion of RQ3 using network analysis provides a more detailed

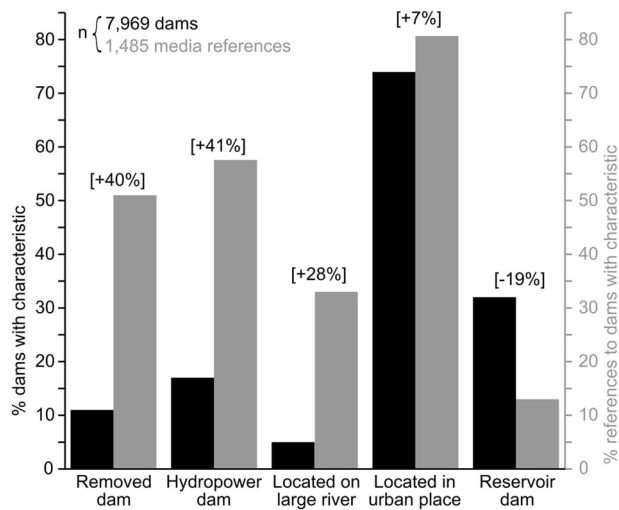


Fig. 4 Summary statistics of dams with media references. Bracketed numbers represent difference between proportion of dams with characteristic and proportion of media references to dams with the characteristic, in percentage points

investigation of finer-scale dam removal news media coordination in New England.

Social-ecological characteristics of newsworthy dams (RQ2)

Our results demonstrate that a minority of dams with certain social-ecological characteristics are more frequently covered in media articles (Fig. 4), as news coverage focuses on those dam that are removed, used for hydropower, located on the mainstem of rivers, or located in urban areas. For example, 11% of dams in the media sample have been removed as of 2019 (NEST 2017), but these dams account for 51% of all media references. This result is not surprising in part because we focused our media search on dam removal. However, the finding that a search for dam removals yields many occurrences of dams that have not been removed underscores the primacy of removal as a news frame. Further, 17% of the dams generate hydropower (FERC 2019) but account for 52% of all media references. Dams located on large mainstem rivers (USGS 2019) account for 5% of referenced dams, but they represent 33% of all media coverage. Similarly, dams that provide a means of fish passage (NEST 2017) account for 15% of dams, but represent 25% of all media coverage. Though dams with these characteristics represent the minority of all total dams, they account for a significantly larger relative portion, and in some cases a majority, of media references. Additionally, most documented New England dams are located in urban places, or towns with population greater than 2500 (USDA 2019). Media representations reflect this pattern with most references to dams in urban areas. However, there are other characteristics that are associated with more limited media

attention. For example, reservoir dams do not receive a commensurate level of media attention. Reservoir dams account for 32% of the geodatabase (NEST 2017), but these account for only 13% of all media references.

Because dam removals are often highly contentious (Jørgensen and Renöfält 2013; Fox et al. 2016; Brummer et al. 2017), we expected to see dams that have been removed or are being considered for removal given more attention in news reporting regardless of sampling approach, and this was the case. The other characteristics studied here—hydropower dams, coastal dams, reservoir dams, and urban dams—indicate the significance of dams in broader social-ecological systems. Energy production is often seen as a critical asset of hydropower dams (Yüksel 2009). However, several hydropower dams were removed or modified in Maine over the last few decades when decision makers considered their negative ecological impacts to far outweigh their capacity for energy production (Crane 2009; Opperman et al. 2011). These dams were located near the mouths of large rivers and blocked a significant amount of habitat for a diversity of sea-run fish species, including the endangered Gulf of Maine population of Atlantic salmon (Martin and Apse 2011; Watson et al. 2018; Roy et al. 2018). Lack of media coverage for reservoir dams may represent the significant practical and public challenges of lowering water levels or removing ponds entirely (Jørgensen and Renöfält 2013; Fox et al. 2016). Reservoir dams tend to be more disruptive to natural ecosystem conditions and are therefore more expensive to maintain or remove (Born et al. 1998; Stanley and Doyle 2003). Reservoir drawdown also causes immediate and uncertain impacts for shoreline properties (Hanson et al. 2002; Lewis et al. 2008). Frequent media references to dams in urban places connect with a greater abundance of dams in developed areas and reflect the impact of ecological restoration in urban waterways (Hychka and Druschke 2017).

All dam decisions incur a cost that may be the determining factor for dam removal (Born et al. 1998; Blachly and Uchida 2018). Of all articles within our corpus, 59% of these reference decision costs. Of the articles that primarily reference Edwards Dam, a \$7.3 M removal project, 52% of these refer to cost. In comparison, 63–79% of the stories covering dam removals on the Penobscot River refer to cost, while only 41% of articles covering Kesslen Dam, an extant dam, refer to cost. Cost is mentioned in most articles, but in terms of media interest it does not appear to be any more substantive than other dam characteristics studied in this analysis.

The contentious nature of conversations surrounding water resources (Hopke 2012) and dam removal specifically (Fox et al. 2016) may further accentuate the importance of previously removed dams in news media. In other words, dams that have been removed may hold a greater

significance for news media, or newsworthiness, that can help frame conversations about other dam decisions and potentially influence public opinion about dam removal in general. In the following section we build from this quantitative analysis to take a qualitative look at dams that are considered newsworthy due to their frequent use in news media and identify how they are used in conjunction with other dams to help frame dam removal narratives.

Framing new dam removals with past newsworthy dams (RQ3)

Newsworthy dam removals with greater total media references tend to get co-referenced with many other dams across New England. This observation aligns with general findings in agenda-setting research where news articles often reference previous newsworthy topics to develop a more accessible and relatable description of a topic (de Loë 1999; Fischlein et al. 2014). High numbers of coincident references for newsworthy dams indicate their importance in framing decisions about dams across scale (Fig. 5). As described above, Maine dams are more frequently represented in news media than other New England dams and comprise all top ten dams ranked by total references (Fig. 5a, b). Combined, total and coincident references suggest that Edwards Dam is especially newsworthy with total references exceeding two hundred and coincident references tallying close to three hundred. Further, the Edwards Dam is the only example with coincident references in all six New England states. Establishing connections between dams is an important pattern in news media, as most dam references occur in conjunction with other dams. All but one of the top ten dams has a coincident reference sum that exceeds the total reference sum. Coincident references signify links spanning multiple states in New England, representing the spatial scope and potential influence of dam decision media coverage (Fig. 5a, c). Due to the perceived importance of Maine dam removals and because we have no consistent way to standardize both interstate and intrastate coincident references, we focus this part of our analysis on Maine dams and their media-based connections across New England and the nation.

Based on a combination of our network analysis and qualitative interpretation of media articles, there are two main explanations for the pattern of coincident references. First, some dam decisions were intentionally coordinated for multiple dams, encouraging news media to reference these collectively within a single article. In these cases, news articles focus on the interconnected nature of these dam removal projects and provide information and news narratives in ways that can shape perspectives about each decision's broader implications. This was the case with dams associated with the Penobscot River Restoration

Project (Day 2006; Opperman et al. 2011), including Veazie, Great Works, Howland, and Milford Dams (Fig. 5). For example, an article published in the *Bangor Daily News* on June 14, 2016 stated “The latest milestone: The construction of a fish bypass—the “big river” that was built around the Howland Dam. That achievement followed the destruction of dams at Great Works in Bradley (2012) and Veazie (2013–14).” In general, dam decisions that are coordinated together typically lead to higher coincident/total reference ratios, indicating that most dam media references are coincident with other related dams and are not isolated occurrences.

Second, new dam removal efforts are framed in terms of past decisions to keep, remove, or modify dams. These dam decisions are not specifically coordinated, yet journalists identify enough similarities to help frame future stories focused on potential decision alternatives and outcomes. An article published in the *Portland Press Herald* on June 20, 1999 demonstrates how Edwards Dam functions as a recurrent frame: “Conservationists across the country are hoping that Edwards Dam’s removal will open the way for the removal of many more [...] Heading the list for removal in Maine may be Veazie Dam, the first obstacle faced by Atlantic salmon and other sea-run species when they ascend the mighty Penobscot River.”

The scale of news publishers provides additional indication of newsworthiness. For example, Edwards Dam and the dams involved in the Penobscot River Restoration Project are frequently referenced by national-scale news publishers such as *The New York Times* (Edwards: 12, Penobscot: 7), *Washington Post* (Edwards: 4, Penobscot: 1), *LA Times* (Edwards: 5, Penobscot: 1), *Boston Globe* (Edwards: 12, Penobscot: 6), *Wall Street Journal* (Edwards: 2), and *USA Today* (Edwards: 3). Articles often pair these dams with other high-profile dams outside of New England, with particular focus on U.S. west coast dams, to help frame the story of dam removal at a national scale. A front-page article published in the *LA Times* on June 21, 1998 shows this framing strategy:

Interior Secretary Bruce Babbitt cleared the way for the removal of the Edwards Dam in Maine, which had blocked 17 miles of prime fish-spawning habitat for 160 years. On Washington State’s Olympic Peninsula, the administration has budgeted \$86 million for removal of one of two dams blocking salmon passage on the Elwha River. Other dam removal projects are under consideration from Michigan to California.

However, it is also important to note differences in the dam landscape across different regions of the world. The types of dams and trends in dam removal found in New England are like those found in Europe and other portions

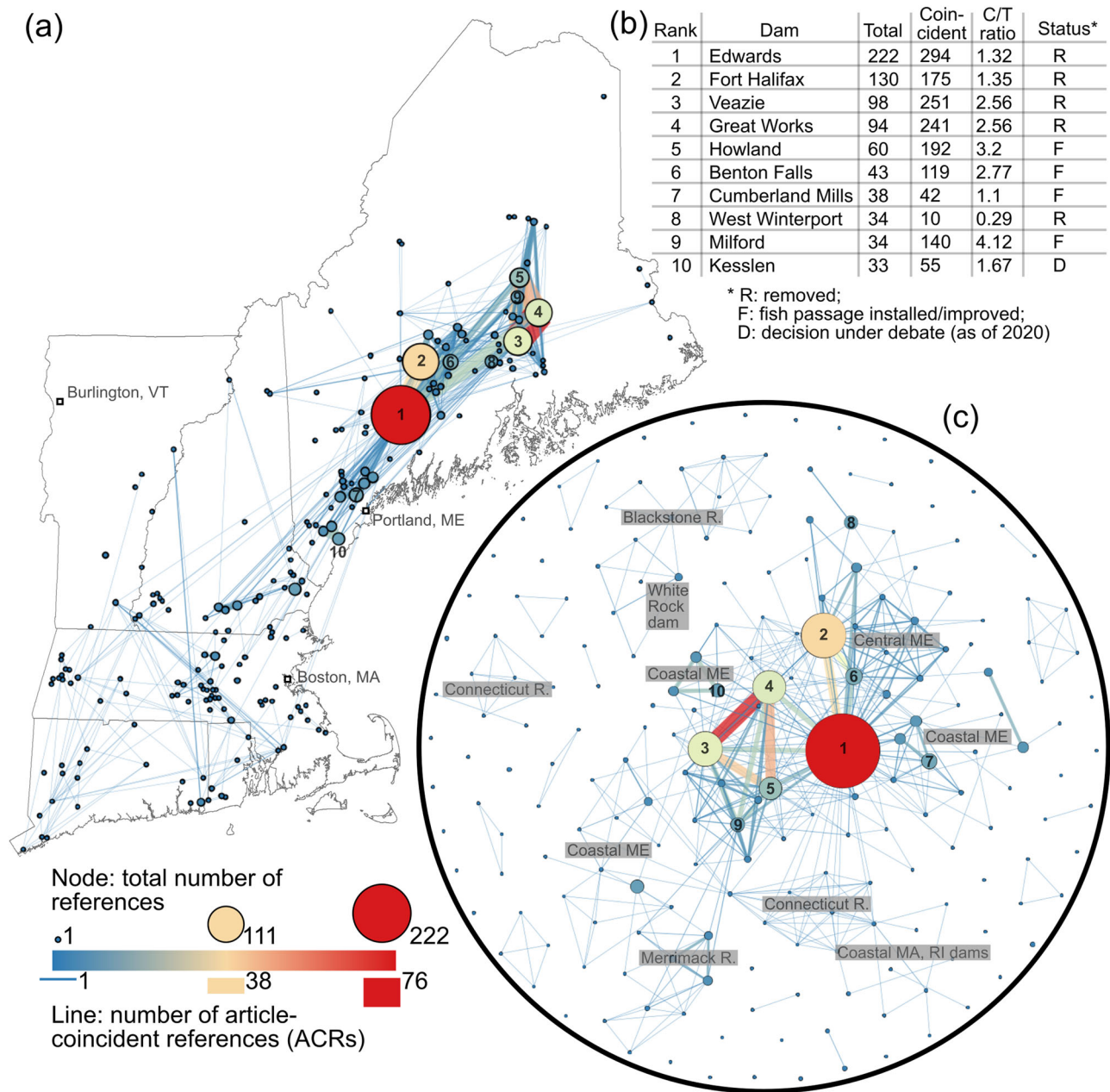


Fig. 5 **a** Georeferenced network map of total media references for New England dams (nodes) and article-coincident references connecting dams in single articles (lines). Larger nodes indicate greater total references. Thicker lines indicate greater number of coincident references, dam article references that coincide with references to other dams, potentially connecting multiple dams within a single article. **b** Table data of top 10 referenced dams, all occur in Maine and many connect to out of state dams through coincident references. Total:

abundance of total references; Coincident: abundance of coincident references, C/T ratio: ratio of coincident and total references. **c** Radial view of network map provides clearer distribution of media reference clusters, dominated by dams in Maine, with surrounding clusters for other major locations in New England. Dam point data republished from (NEST 2017) under a CC BY license, with permission from the Data Discovery Center, original copyright 2016

of the United States and Canada where small, old mill dams blanket the landscape (Ding et al. 2019). However, this analysis is not patently applicable to the large, modern dams that serve entire cities dependent on power and water production (Biswas and Tortajada 2001), such as in the western United States and in developing countries.

For projects that attempt to coordinate decisions across a system of dams, our analysis shows that dams that were ultimately removed received more attention compared to extant dams (Fig. 5b). Past decisions about dams are frequently used to frame dams where there is a debate or conflict related to a pending decision. Further, dams that featured upgraded fish passageways or turbines were

mentioned comparatively fewer times overall but were more likely to be mentioned in connection with related dam removals. These dams exhibit relatively high coincident and total reference ratios. This suggests that upgraded dams are used as supporting examples in news stories that tend to focus on and emphasize dam removal and that these dams may be candidates for future removal or alternative decisions. For example, an article published in the *Bangor Daily News* on October 7, 2003 describes the Penobscot River Restoration Project and the “need to raise another \$25 million to remove the Great Works and Veazie dams and to decommission the Howland Dam and outfit it with a hydraulic fish lift....” The article goes on to refer to the restoration project as a “‘Win-win’ agreement,” referring to the coordination of multiple dam decisions to improve the ecological health of the river while avoiding any losses in hydropower production (Opperman et al. 2011).

Plans for dam removals or other related decisions can also draw legislative and legal challenges, often halting or slowing decisions, which may contribute to their newsworthiness. In an example from the *Portland Press Herald* on March 21, 2010, the removal of the Fort Halifax dam came to completion “after seven years of debate, legal challenges and frustration by supporters and opponents. State officials required a fish passage on the river, by either a fish lift or dam removal, and power company officials opted for removal.” Final decisions for removal are often up to those with ownership of the dam during the decision-making process and their response to pre-existing regulations imposed by state or federal government.

News media serve a key influence in the social construction of environmental perceptions by shaping how, when, and in what form complex social-ecological topics are presented to public audiences. Our results show that the distribution of news media coverage of sustainability issues, in this case focused on dams, does not necessarily correlate with ecological or landscape-level characteristics associated with these issues. Further, news media discourse about dams is dominated by a handful of highly influential and newsworthy cases, like the Edwards dam. Triangulating news media and geospatial data can help link insights on how each dam is framed relative to past dam decisions, possible influences on removal decision based on the magnitude of total and article coincident media references, and important quantitative information on characteristics of newsworthy dams.

Conclusion

We developed and used DAMMDA—a methodology for pairing a regional geodatabase of dams with a corpus of news media—to determine the presence of dams in local to national-scale news media and to better understand how news

media articles draw upon previous dam decisions to help frame information about new or future dam decisions. We find that the general spatial patterns of dams referenced in news media do not necessarily correlate with the spatial distribution of dams or dam removals within New England. The majority of media references to dams in New England occur in Maine, though by standardizing the frequency of media references we reveal a strong southwest-northeast linear trend in media attention located near the coast. Beyond this pattern, we identify five distinct clusters of dam removals that have occurred in New England. Several key characteristics appear to contribute to the relative newsworthiness of dams, including whether the dam has already been removed, produces/produced hydropower, occurs/occurred on a large mainstem river, and is/was located within urban areas. Multivariate analysis would provide insight on whether news reference frequency is sensitive to interrelationships among these characteristics. Article coincident references to multiple dams within a single article provide a key indicator of how past newsworthy dam projects are used to frame discussions about new and future dam decisions. Results indicate that highly newsworthy dams, such as the Edwards Dam and the dams associated with the Penobscot River Restoration Project, have a broad influence in media-related discussions about dam removal throughout New England.

Beyond the immediate focus on dams, news media, and geospatial patterns, we identified numerous opportunities to apply DAMMDA for analyzing connections between media and myriad sustainability challenges. As noted, media discourses can provide valuable perspective about complex sustainability topics and potential influences on how people access information and make sense of complex social-ecological issues. DAMMDA provides a basis for powerful systems-based and interdisciplinary analyses of a host of potentially contentious sustainability and natural resource topics, including renewable energy (Aydin et al. 2010; Latinopoulos and Kechagia 2015), carbon capture and storage (Feldpausch-Parker et al. 2015), air quality monitoring (Jiang et al. 2015), brown-fields redevelopment (De Sousa 2003; Chrysochoou et al. 2012) and beyond. News media provide an important and under-utilized resource for understanding factors that can influence how people make sense of sustainability challenges and how past decisions can be used to frame future decisions. Use of media discourse analysis is expected to grow (for example, the [U.S. Drought Monitor now detects emerging impacts](#) using the approach). Taken together, spatial relationships between sustainability issues, like dams, and media coverage; social-ecological characteristics and newsworthiness; and patterns in news media framing over time provide a window onto the complex and interconnected set of social and material factors that can shape natural resource decision making.

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Compliance with ethical standards

Conflict of Interest The authors declare no competing interests.

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