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ORIGINAL ARTICLE

Looking under the hood of local adaptation plans: shedding light on the actions prioritized to build local resilience to climate change

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Abstract In the face of a changing climate, many United States (US) local governments are creating plans to prepare. These plans layout how a community is vulnerable to existing and future changes in climate as well as what actions they propose taking to prepare. The actions included in these plans provide insight into what local governments feel they have the ability to undertake, as well as what actions they believe are important to building resilience. To date, little to no analysis has been conducted on the content of these plans, leaving researchers, practitioners, and those supporting communities with limited understanding of what gaps need to be filled or how best to support locally prioritized climate action. This paper analyzes the content of 43 stand alone climate adaptation plans from US local communities to identify the types of actions proposed and how those actions compare to what researchers indicate the communities should be prioritizing based on regional climate projections. The results indicate that local communities include numerous and varied actions in their adaptation plans and that the majority of communities are selecting actions that are theoretically appropriate given projected changes in regional climate. Yet some types of actions, such as building codes and advocacy, are not being widely used. These results contrast with previous studies, which found that local communities focus primarily on capacity building approaches. Findings also demonstrate that plans rarely contain significant details about how actions will be implemented, raising questions about whether plans will translate into real-world projects.

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1 Introduction

The imminent and far-reaching consequences of climate change have made adaptation, or actions to reduce the harm of climate change impacts, an imperative (Bierbaum et al. 2013; IPCC 2014a, b). Most of the least-developed countries have developed National Adaptation Programs of Action (The World Bank 2010), some United States (US) states are creating voluntary climate action plans (Ray and Grannis 2015), and many US tribal and local governments are creating climate adaptation plans (Shi et al. 2015; Woodruff and Stults 2016). These plans generally profile physical and social vulnerabilities to existing and future changes in climate and identify actions to build resilience to projected impacts (Woodruff and Stults 2016).

While action at all scales is needed, climate-related impacts are most pronounced at the local level (Baker et al. 2012; Moser and Pike 2015). This reality, combined with the fact that more than 80% of the US population currently lives in urban areas (Bureau 2012), means that any effort to prepare for climate change must emphasize action at the local level. In the US, the importance of local level adaptation to climate change can be seen in the inclusion of local voices in the President's State, *Local and Tribal Leaders Task Force on Climate Preparedness and Resilience*, in the local examples in the 2014 US National Climate Assessment, and in the investments that philanthropies are making in local adaptation initiatives (e.g., The Kresge Foundation, Bloomberg Philanthropies, 100 Resilient Cities).

US local governments have the authority and tools to address climate impacts including land use planning, landscaping ordinances, infrastructure improvements, and floodplain management. Yet, there is no national framework for climate adaptation requiring communities to consider climate change, establishing climate projections to be used for planning, or even specifying an appropriate adaptation planning process. As such, innovation has occurred at the local level. Since 2005, more than 40 communities in the USA have created stand alone climate adaptation plans, with potentially hundreds more embedding climate considerations into other planning approaches (e.g., sustainability plans, drought or water management plans, climate action plans (Quay 2010; Shi et al. 2015; Woodruff and Stults 2016)). The growth in local government climate planning combined with the lack of a federal framework makes the US an interesting place to study the variety of local adaptation efforts.

Despite the growing awareness of the importance of climate adaptation, few analyses have explored what actions US local communities are including in their climate adaptation plans and, therefore, what actions they are prioritizing to prepare for climate change (Fidelman et al. 2013). Without knowledge about locally prioritized adaptation actions, researchers, practitioners, and those seeking to help local communities adapt to climate change will continue to have limited understanding of the state of practice and how to effectively assist in implementing adaptive actions. This research addresses this need by answering three questions: (1) what are US local governments planning to do to prepare for climate change, (2) how do these actions align with the risks or vulnerabilities faced by these local governments, and (3) do local governments provide details that will support the implementation of actions they identify?

In the following section, we begin by looking at the state of local adaptation planning in the US and abroad, paying particular attention to studies that identify the types of adaptation

actions prioritized in local adaptation plans. Next, existing typologies of adaptation action are identified in order to help organize adaptation actions proposed in our sample into a conceptual framework that permits multi-site comparison. We then briefly discuss proposed impact-specific adaptation actions in both the peer-reviewed and gray literature in order to understand what actions are recommended for addressing place-based vulnerabilities. We conclude this review with a brief overview of factors known to influence plan implementation before transitioning into our research methods. We then present our findings from an analysis of adaptation actions contained in 43 stand alone climate adaptation plans from US local communities. We conclude by discussing what our findings indicate about the state of local adaptation planning in the US and what opportunities exist to improve the next generation of climate adaptation planning and action.

1.1 The state of local adaptation planning

Over the last several years, a strategic process to plan for climate change that includes five main steps has been proposed (Fig. 1) (Bierbaum et al. 2014; Mimura et al. 2014). Researchers have undertaken surveys and detailed case studies to more deeply understand how communities are progressing through this cycle. For example, a 2011 survey of local communities' adaptation initiatives from around the world found that nearly 40% of the 468 local respondents had conducted or were in the process of conducting a vulnerability or risk assessment (Carmin et al. 2012). Of the US respondents (156), 27% were in the vulnerability analysis or planning phases, and only 9% were in the implementation phase (Carmin et al. 2012; Shi et al. 2015). The authors concluded, "most cities are still at the earliest stages of planning, having just started to discuss or think about the best way to proceed" (Carmin et al. 2012 p. 28).

To a large extent, the academic literature reflects communities' progress in the adaptation planning process, with the first phase (conducting a vulnerability or risk assessment) receiving significantly more attention than the later phases (Stults et al. 2015). Specifically, most of the literature on adaptation discusses methodologies for identifying vulnerabilities or the results of specific vulnerability assessments (Berrang-

Fig. 1 General adaptation process (per the adaptation chapter of the 2014 US National Climate Assessment; Bierbaum et al. 2014)

Ford et al. 2011; Eakin and Luers 2006; Maru et al. 2011; Smit and Wandel 2006). Less attention has been dedicated to discussing adaptation actions that local practitioners are undertaking, and even less attention has been paid to profiling the implementation and evaluation of specific adaptation actions (Bierbaum et al. 2014; Mimura et al. 2014).

The research that does exist on adaptation actions and implementation tends to focus on adaptation actions in a specific place (i.e., case study analysis) or high-level comparisons of single adaptation actions across a small subset of communities. For example, in a multi-site analysis, Abt Associates (2016) conducted interviews and desktop research to understand how 17 communities were preparing for climate change. The authors created detailed case studies highlighting a single action each community had undertaken to prepare for climate change or climate variability. They concluded that local communities are using a wide variety of tools to address local vulnerabilities, such as implementing land use regulations to avoid climate-related exposure, installing green and physical infrastructure to reduce climate-related sensitivity, and using education to increase adaptive capacity (Abt Associates 2016). In addition, every community analyzed included at least some dimension of capacity building in their adaptation activities.

Capacity building is defined as "the practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society, or organization to respond to change" (Intergovernmental Panel on Climate Change 2014a, b, p. 1759). The emphasis on capacity building in local adaptation planning has repeatedly been cited in detailed place-based case studies (Fidelman et al. 2013; Moloney and Fünfgeld 2015; Petersen et al. 2014; Welsh et al. 2013), in multiple-site case studies (Boyer et al. 2016; Berke et al. 2011; Biagini et al. 2014; Engle 2013; Quay 2010), and in adaptation meta-analyses (Bierbaum et al. 2013; Hansen et al. 2013; Hughes 2015). For example, in an analysis focused on the United Kingdom (UK), Tompkins et al. (2010) identified over 300 examples of "adaptation practice" (p. 627), with capacity building being the most frequently used type. In similar research looking at climate adaptation actions prioritized in 57 federal, state, and local plans in Australia, the UK, and the US, Preston et al. (2010) found that the majority of actions (72%) focused on "low-risk capacity building," with the most frequent action being "gathering and sharing more information" (p. 423).

1.2 Typologies of adaptation action

While capacity building is a commonly discussed strategy, there are a variety of other types of adaptive actions that can help communities prepare for climate change. In the last several years, researchers from the climate, planning, and disaster fields have created typologies to organize the types of actions that can help reduce vulnerability or increase resilience to natural disasters and climate change (Biagini et al. 2014; Cutter et al. 2008; Felgenhauer and Webster 2013; Ford et al. 2013; Smit and Skinner 2002; Tompkins et al. 2010). These typologies generally group actions based on one of several attributes: (1) the timing of activity relative to the impact (e.g., anticipatory versus reactive), (2) the intent associated with the action (e.g., autonomous versus planned), (3) the geospatial scope of the action (e.g., local versus regional), (4) the form of the action (e.g., financial versus physical infrastructure), or (5) the degree of change in existing systems associated with the action (e.g., incremental versus transformational (Biagini et al. 2014; Smit and Skinner 2002)).

Form-based typologies (no. 4 above) are the most prevalent (Biagini et al. 2014), but there is a great deal of variation in existing form-based typologies. Berrang-Ford et al. (2011) used the categories of "intention to act" and "action" to classify adaptation activities found in English language peer-reviewed articles. In this approach, the authors classify things such as the assessment of vulnerability or risk as intention to act, as these do not directly lead to reductions in vulnerability (Berrang-Ford et al. 2011). In contrast, things such as monitoring, increasing awareness, building partnerships, and retreating were considered adaptation actions. Taking a similar approach, Lesnikowski et al. (2011) and Lesnikowski et al. (2013) classify adaptation activities into three categories: recognition, groundwork, and adaptation action. Recognition activities demonstrate that an entity is aware of a climate-related impact but has not yet taken action. Groundwork activities are preliminary steps that inform and prepare stakeholders for action but do not constitute actual changes in policy, programs, or the delivery of services (e.g., vulnerability assessments, research, and networking (Lesnikowski et al. 2013)). Adaptation actions, according to Lesnikowski et al. (2011), are tangible actions taken to "alter institutions, policies, programs, built environments, or mandates in response to experienced or predicted risks of climate change" (p. 1155).

Building on these existing typologies, Biagini et al. (2014) classify 158 distinct adaptation projects financed through the Global Environment Facility into ten categories: (1) capacity building, (2) management and planning, (3) changes in or expansion of practice or behavior, (4) policy, (5) information, (6) warning or observing systems, (7) physical infrastructure, (8) green infrastructure, (9) financial, and (10) technology. Similar to Tompkins et al. (2010) and Preston et al. (2010), the authors found that the majority of activity was related to capacity building: nearly every project analyzed in the GEF adaptation portfolio included an action focused on capacity building. Unlike other research, however, the authors also found a significant number of activities focused on "management and planning" and changing "practice and behavior" (Biagini et al. 2014). Despite Biagini et al.'s (2014) finding, however, the majority of research to date suggests that capacity building remains the dominant type of adaptation action prioritized in adaptation planning.

1.3 Selecting adaptation actions appropriate for projected changes in climate

While capacity building is critical to enable and enhance future adaptation efforts, it alone is not sufficient to address the climate impacts that many communities are already experiencing. In a study of adaptation activity in the US state of California, Bedsworth and Hanak (2010) identified 49 potential adaptation actions to reduce the vulnerability of six sectors to climate change. Similarly, a number of other researchers and policymakers have identified adaptation actions to respond to climate impacts across a variety of sectors (Boswell et al. 2012; Fu and Tang 2013; Jenerette et al. 2011; Juhola et al. 2013; Neill et al. 2009; Pincetl and Hogue 2015; Welsh et al. 2013). Eisenack et al. (2011) identify 245 adaptation actions recommended in the peer-reviewed and gray literature for transportation. They note that the gray literature provides more concrete actions aimed at responding to specific climate impacts than the peer-reviewed literature (Eisenack et al. 2011). Indeed, international organizations, federal agencies, state governments, non-profits, professional organizations, and foundations have all developed adaptation guidance and tools to help local governments identify actions to address their place-based vulnerabilities (American Planning Association 2011; California Emergency Management Agency 2012;

Institute for Sustainable Communities 2010; Intergovernmental Panel on Climate Change 2012; National Institute of Standards and Technology 2016; New York State 2016; United Nations Environment Programme 2013; University of Washington and ICLEI 2007; US Environmental Protection Agency 2014).

While the most appropriate actions vary from community to community, these guides and tools provide a comprehensive overview of the types of actions that should be considered for different climate impacts and sectors. To help organize proposed actions, we reviewed the peer-reviewed and gray literature mentioned above to identify and organize recommended actions to combat specific climate-related impacts (Table 1).

1.4 Plan implementation

Identifying sector- and impact-specific adaptation actions is an important step in planning for climate change. But a community can build resilience only if the actions identified during the planning phase are implemented. Unfortunately, time and resource constraints limit the ability to assess the implementation of adaptation actions in all US communities. Consequently, researchers within the planning and policy domains have devised a series of criteria that are frequently used to gauge the likelihood that a plan will be implemented, including the following:

- Identification of parties responsible for action implementation (Bassett and Shandas 2010; Berke and Lyles 2013; Berke et al. 2012; Brody and Highfield 2005)
- Identification of parties responsible for monitoring and evaluating implementation of actions as well as the overall plan (Berke et al. 2012)
- Articulation of a measurable target and indicator to measure the successful implementation of each action (Bassett and Shandas 2010)
- Establishment of a timeline for implementing each action (Berke et al. 2012; Brody and Highfield 2005; Horney et al. 2012)
- Identification of costs and funding source to implement each action (Bassett and Shandas 2010; Hughes 2015; Lyles and Stevens 2014)
- Provision for updating the plan as new information becomes available, including a timeline for when updates need to be made (Berke et al. 2012; Brody and Highfield 2005; Highfield and Brody 2013)
- A strategy to monitor the plan's overall effectiveness (Brody and Highfield 2005)

Using a combination of these criteria, researchers have evaluated hazard mitigation, sustainability, and climate action plans, finding that plans regularly omit important implementation details. For example, in a meta-analysis of plan quality studies, Berke and Godschalk (2009) found that plans consistently "specify organization responsibility and timelines for actions for implementation and monitoring" but omit other important elements associated with plan implementation, such as funding source. Similarly, in an analysis of state-level drought mitigation plans, Fu et al. (2013) found that most plans included implementation responsibility details but omitted details pertaining to financial and/or technical support, details regarding future plan updates, and timetables for implementation. Omissions such as these raise concerns about whether plans will translate into on-the-ground, vulnerability reducing actions.

Table 1 Summary of proposed climate adaptation actions based on guidance provided in the gray and peer-reviewed literatures. Column one denotes the six major climate drivers, column two the local impacts most likely to occur due to those drivers, column three examples of commonly promoted actions within the peer-reviewed and gray literature to adapt to those impacts, and column four denotes the type of action, based on the categorization used in the analysis. This table is not meant to identify every possible potential action, only the types (column four) proposed to respond to projected climate impacts (column two)

Climate driver	Impact	Suggested actions	Type
Temperature change	Extreme heat	Open additional cooling centers during extreme heat	Practice and behavior
		Improve early warning systems for extreme heat	Technology
		Use urban greening to reduce temperatures	Green infrastructure
		Install cool roofs	Physical infrastructure
		Update heat response plan in light of climate change	Planning
	Vector-borne disease	Increase monitoring of disease	Research and monitoring
		Enhance vector-control management practices	Practice and behavior
	Ecosystem impacts	Assist migration of flora and fauna	Practice and behavior
		Purchase upland ecosystems to allow species to migrate	Land use
	Ocean acidification	Remove CO2 from oceans	Technology
		Continue to monitor changes to ocean pH and ecosystem impacts	Research and monitoring
	Air quality	Improve early warning systems	Technology
		Advocate for stricter air quality standards	Advocacy
		Install air quality monitoring stations	Research and monitoring
		Change timing of behaviors, such as sports team practices, during days with poor air quality	Practice and behavior
		Increase urban forest and greening	Green infrastructure
	Energy demand	Conserve energy	Energy conservation
		Implement green building codes	Building codes and design standards
	Infrastructure damage	Use alternative materials that are resistant to heat damage	Physical infrastructure
		Establish stricter building codes	Building codes and design standards
		Conduct maintenance more frequently	Practice and behavior
Sea level rise	Inundation	Facilitate managed retreat from areas at risk of inundation	Land use
		Preserve undeveloped shoreline	Land use
		Mandate real-estate disclosures	Practice and behavior
		Educate homeowners and members of the private sector	Education and outreach
		Protect structures	Physical infrastructure

Table 1 (continued)

Climate driver	Impact	Suggested actions	Type
		Maintain or restore coastal wetlands	Green infrastructure
		Create a "no-build" zone or district	Policy
		Plan for relocation	Planning
		Elevate and strengthen buildings against more frequent flooding	Building codes and design standards
			Physical infrastructure
	Ecosystem impacts	Assist migration of flora and fauna	Practice and behavior
		Establish transfer of development rights program	Land use
	Salt water intrusion	Relocate wells and septic tanks	Land use
		Install a desalinization plant	Technology
		Expand water and sewer infrastructure	Physical infrastructure
Decreased precipitation	Reduced water supply	Expand and diversify water supply	Practice and behavior
		Increase water storage	Physical infrastructure
		Enhance rainwater infiltration	Green infrastructure
		Conduct water management planning	Planning
		Reduce water demand	Water conservation
		Increase water reclamation and purple pipes	Physical infrastructure
		Update landscape ordinance	Policy
		Improve information used for water management	Technology
	Ecosystem impacts	Initiate water conservation programs	Water conservation
	Reduced water quality	Enhance water treatment processes	Practice and behavior
		Protect and restore riparian buffers	Green infrastructure
			Land use
Increased precipitation	Flooding	Increase stormwater management capacity	Physical infrastructure
		Encourage low-impact development	Land use
		Capture stormwater where it falls	Green infrastructure
		Reduce number of properties at risk of flooding and stormwater damage	Land use
		Plan for relocation	Planning
		Create a no-build zone or district	Policy
		Make properties and infrastructure more resilient to flooding	Physical infrastructure
			Building codes and design standards
		Promote the purchase of flood insurance	Education and outreach
			Financing
	Infrastructure damage	Strengthen buildings to prevent damage	Physical infrastructure

Table 1 (continued)

Climate driver	Impact	Suggested actions	Type
		Install or restore green infrastructure to help lessen flood damage to built infrastructure	Green infrastructure
		Relocate vulnerable infrastructure	Land use
		Strengthen building codes	Building codes and design standards
	Ecosystem impacts	Maintain natural vegetation for stormwater retention	Green infrastructure
	Reduced water quality	Make adjustments to water treatment processes	Practice and behavior
		Capture stormwater where it falls	Green infrastructure
		Protect and restore riparian buffers	Land use
Extreme events	Storm surge	Preserve natural shorelines	Land use
		Protect and enhance natural breakwaters	Green infrastructure
		Install floodgates and other structural protection	Physical infrastructure
		Educate homeowners and members of the private sector	Education and outreach
		Create a no-build zone or district	Policy
		Strengthen buildings to prevent damage	Building codes
	Power outages	Create renewable energy systems for back-up power	Technology
		Strengthen energy infrastructure	Physical infrastructure
	Hurricanes/coastal storms	Conduct evacuation planning	Planning
		Strengthen building codes	Building codes and design standards
		Educate homeowners and members of the private sector	Education and outreach
		Maintain or restore natural systems to serve as a storm buffer	Green infrastructure
		Convert land adjacent to coastline into parks	Land use
		Ensure that evacuation routes are usable during disaster	Physical infrastructure
	Erosion	Restore wetlands and dunes	Green infrastructure
		Install revetments or other pieces of hard infrastructure	Physical infrastructure
	Thunderstorms/winter storms	Implement ice and snow removal programs	Practice and behavior
		Retrofit homes and businesses to withstand extreme weather	Physical infrastructure
		Strengthen building codes	Building codes and design standards
		Educate homeowners and members of the private sector	Education and outreach
	Ecosystem impacts		Land use

Table 1 (continued)

Climate driver	Impact	Suggested actions	Type
		Purchase less vulnerable land and create migration corridors	
		Establish transfer of development or purchase of development rights programs	Land use
	Infrastructure damage	Strengthen building codes	Building codes and design standards
		Maintain or restore natural systems to serve as a storm buffer	Green infrastructure
		Harden physical infrastructure	Physical infrastructure
	Extreme wind	Strengthen building codes to address extreme winds	Building codes and design standards
		Conduct regular tree maintenance	Practice and behavior
Wildfire	Infrastructure and property damage	Design buildings and infrastructure to minimize vulnerability to fire	Building codes and design standards
			Physical infrastructure
		Educate homeowners about tree maintenance and vegetation cover	Education and outreach
		Promote fuel breaks and defensible space	Practice and behavior
		Regulate development in the wildland-urban interface	Land use
		Manage fuel load through thinning and brush removal	Practice and behavior
	Air quality	Improve early warning systems	Technology
		Change timing of outdoor activities to correspond to times with better air quality	Practice and behavior

2 Methods

To understand which adaptation actions local governments prioritize, how these actions align with expected climate impacts, and the likelihood that actions will be implemented, content compiled during a previous plan evaluation study was reviewed and reanalyzed (omitted for anonymity). In the earlier study, content analysis was used to evaluate 44 stand alone, local adaptation plans in the USA against seven principles of plan quality: (1) goals, (2) fact base, (3) actions, (4) public participation, (5) inter-organizational coordination, (6) implementation and monitoring, and (7) uncertainty. In this paper, we focus exclusively on the *actions* principle (Appendix 1) and *implementation and monitoring* principles (Appendix 2).

The previous study focused solely on determining the presence or absence of adaptation action types; no attempt was made to determine how frequently given actions were proposed or how appropriate proposed actions were based on projected changes in climate. Moreover, the previous study classified adaptation actions based on existing typologies of actions. While

valid, using existing typologies of adaptation action may misclassify actions if it represents a new type of action not included in existing typologies. For example, the previous study (omitted for anonymity) found that 91% of plans had actions that did not fit within existing typologies, which the authors classified as "general strategies." This means that a significant number of strategies are not properly captured within existing typologies of adaptation action and, therefore, may not be considered when evaluating the types of actions local governments prioritize for adaptive action.

2.1 Data

The data set for this analysis was created using a content analysis-based plan evaluation in which plans are systematically read to determine whether they fulfill pre-determined metrics. Assessing the presence/absence of criteria allows the conversion of text to a quantitative measurement of plan quality, which eases comparisons between plans and permits statistical analyses. Plans were evaluated on two principles: (1) actions and (2) implementation and monitoring. We used 23 metrics to capture content within the "actions" principle (Appendix 1) and 16 metrics to capture content related to the "implementation and monitoring" principle (Appendix 2). Metrics within the actions principle fall into two categories: (1) those that describe the type of adaptation action being proposed (e.g., policy, green infrastructure), for which 15 metrics were initially included and (2) those that help justify the need for the adaptation action (e.g., cost of inaction, co-benefits), for which eight metrics were used (Appendix 1). Within the implementation and monitoring principle, eight metrics focus on providing information that theoretically supports plan implementation, and eight metrics focus on monitoring plan implementation and outlining a process to improve the plan over time (Appendix 2). All 39 of the metrics represent processes and considerations consistently emphasized within the adaptation guidance literature published by academics and international, federal, state, and non-governmental organizations.

To ensure that the plans in the sample were comparable, only plans that were completed between 2007 and 2014, focused on adaptation, resilience, or preparedness, were written by or for a US city or county government and took a comprehensive approach to adaptation were included in the sample (Appendix 3).

Each plan in the sample was coded independently by two trained coders consistent with recommendations from the communication literature on content analysis (Krippendorff 2013) and recommendations from the plan evaluation literature on methodology (Berke and Godschalk 2009; Stevens et al. 2014). Coders used the NVivo version 10 qualitative analysis software package (QSR International Pty Ltd 2012) to analyze each plan. All plans were read within the software and text aligning with metrics was selected, categorized, and saved. By doing this, researchers were able to preserve the text that supported each metric while also determining the presence or absence of each metric, as well as calculate the number of times each metric was mentioned or supported within each plan.

After the coders completed a plan, their quantitative data was compared to identify disagreements on a metric-by-metric basis. All disagreements were discussed and reconciled by referring to the qualitative plan content, and the final, agreed-upon codes were integrated into a master dataset.

2.2 What actions are proposed?

In order to more holistically understand what types of actions are being proposed within plans, we took the coding results and reanalyzed the text associated with the type of actions proposed using an inductive research approach. Each author independently reviewed and classified actions, moving actions to more appropriate types and creating new types of actions, if necessary, to more accurately reflect what the local plans were proposing. To be consistent, all actions were coded based on the action being proposed, not the intent of the action. This meant that if an action was a policy change that would incentivize more resilient building codes, it was coded as being a policy action and not a building code action. By doing this, we were able to code the actions as presented by the plan authors, avoiding the need to interpret the plan authors' intent.

When appropriate, adaptation actions were co-tagged as multiple types. For example, Baltimore MD's action to "encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures" was double tagged as being both a physical infrastructure action and a green infrastructure action. All differences were collaboratively reconciled by referring back to the adaptation plan and looking for similarities between the action in question and other actions.

Through this review, we created four new types of adaptation actions: water conservation, energy conservation, funding, and actions focused exclusively on greenhouse gas mitigation. We also removed the original conservation action type and reclassified actions within this category as either land use or green infrastructure actions. Finally, we reclassified the actions that were originally tagged as being too general into one of the other types of actions, as appropriate. In the end, each adaptation activity was classified as one of 17 types (Table 2).[1]

For each plan, we calculated the total number of actions, the number of action types, and the proportion of each type of action. In addition, we calculated the total number of actions in each type and the number of plans that included a given type of action.

2.3 Do actions align with local vulnerabilities?

To address how these actions align with the climate impacts that communities face, we used the 2014 US National Climate Assessment to determine climate impacts for each of the 43 communities based on its region of the country. For each climate impact identified for the local community or region, a literature review of adaptation action guidance materials developed by international, federal, state, and non-governmental organizations as well as guidance within the peer-reviewed literature was conducted to identify recommended adaptation actions for the different climate impacts and drivers (Table 1). We then determined how those actions would be classified in our draft typology. For example, the *California Emergency Management Agency (CEMA) Adaptation Planning Guide* recommends that a community facing significant sea level rise should consider managed retreat and preserving undeveloped shoreline (CEMA 2012), both of which we would code as land use. The US Environmental Protection Agency recommends communities consider the maintenance and restoration of wetlands to address sea

[1] All of types of adaptation action identified by Biagini were used in our analysis, with the exception of warning or observing systems. In addition, we added *advocacy*, *building codes and engineering design standards*, *energy conservation*, *funding*, *land use*, *research and monitoring*, *water conservation*, and *greenhouse gas mitigation*. This took the total number of action types coded for in this paper to 17.

Table 2 The final 17 types of adaptation actions included in this analysis. Column one lists the type of action, column two briefly describes the action, and column three indicates the source of the action type, including if it has previously been identified as an important adaptation action within the peer-reviewed literature

Strategy type	Description	Source
Advocacy	Strategies to encourage regional partners, state agencies, and other organizations to take adaptation-appropriate strategies	Tompkins et al. 2010
Building codes and engineering design standards	Strategies to improve physical infrastructure's response to changing climate through improved standards or engineering	Travis 2010
Capacity building	Strategies to develop human resources, institutions, and communities, equipping them with the capability to adapt	Biagini et al. 2014; Tompkins et al. 2010
Education and outreach	Strategies focused on increasing public knowledge	Tompkins et al. 2010; Biagini et al. 2014
Energy conservation	Strategies to reduce energy consumption	Grounded theory analysis
Financing	Strategies that use financial (dis)incentives or budget mechanisms to encourage adaptation	Biagini et al. 2014
Funding	Strategies focused on securing capital to implement adaptation-related activities	Grounded theory analysis
Green infrastructure	Strategies that use natural systems or processes to advance adaptation	Biagini et al. 2014
Land use and zoning	Strategies that determine how land will be used and where development will occur	Travis 2010
Physical infrastructure	Strategies to create new physical infrastructure, remove physical infrastructure, or modify how physical infrastructure is built	Biagini et al. 2014; Travis 2010
Planning	Strategies that incorporate understanding of climate science, impacts, vulnerability and risk into government and institutional planning processes, efforts, or existing initiatives	Tompkins et al. 2010; Biagini et al. 2014
Policy	Strategies to create new or revise existing regulations and legislation	Biagini et al. 2014; Tompkins et al. 2010
Practice and behavior	Strategies to modify or expand on-the-ground behavior, operations, management, or programs that affect resilience	Biagini et al. 2014
Research and monitoring	Strategies that focus on gathering information and creating reports, maps, or models; monitoring includes observation or repeated measurements over time	Tompkins et al. 2010; Biagini et al. 2014; Travis 2010
Technology	Strategies to develop or expand climate-resilient technologies such as technologies to improve water use,	Biagini et al. 2014; Travis 2010

Table 2 (continued)

Strategy type	Description	Source
	renewable energy, communications, and early warning systems	
Water conservation	Strategies focused on reducing water consumption	Grounded theory analysis
Greenhouse gas reductions	Strategies that explicitly focus on reducing greenhouse gas emissions	Grounded theory analysis

level rise, which we would code as green infrastructure (Environmental Protection Agency 2014). While not all actions identified during the literature review are included, the actions included in Table 1 demonstrate the types of actions the literature recommends communities consider for each climate driver. Using the material in Table 1, we then determined whether the types of actions proposed in each community's plan aligned with the types of adaptation actions recommended in the peer-reviewed literature based on projected regional climate impacts.

2.4 Will actions be implemented?

Lastly, to assess whether local governments provide detail to support the implementation of adaptation actions, we reviewed the aggregate results from the coding of implementation criteria as well as the supporting text from each plan. Descriptive statistics were calculated to identify similarities and differences across plans.

3 Results

3.1 Types of adaptation actions

Across the 43 adaptation plans in the sample, we identified 3375 discrete actions. On average, each plan included 93 actions. The median number of actions in a plan was 54. Lee County, FL, included the most actions (447), followed by Lafourche Parish, LA (337), and New York City, NY (323). Milwaukee, WI, had the fewest actions (14). However, what qualifies as an action and the level of detail provided about each action varied significantly across the plans in the sample. While Lee County, FL, had the most actions, the plan's authors provided little detail about their proposed actions; many of which were very general (such as "increase public awareness"). Punta Gorda, FL, similarly included many actions that are too general to provide direction on implementation (e.g., "limit development," "use flexible planning," and "stormwater retention"). In contrast, Baltimore, MD, and New York City, NY, provided extensive detail on each action, discussing the motivation for the action, details about what the action entails, and action-specific implementation information.

On average, each plan in the sample included 12 of the 17 adaptation action types. Baltimore, MD, Denver, CO, Keene, NH, and Lee County, FL, included at least one of each of the 17 types of adaptation actions. Fresno County, CA, New York City, NY, Oakland, CA, Punta Gorda, FL, and San Luis Obispo, CA, all included 16 out of the 17 types of adaptation

actions. Two plans included only seven of the 17 types of actions: Guilford, CT, and Seabrook, NH (Fig. 2).

All but one plan (Milwaukee, WI) included research and monitoring actions (Fig. 2). Most of the actions categorized as research and monitoring focused on collecting more information about projected climate impacts on a specific sector or system of concern, researching appropriate adaptation actions, or monitoring the effectiveness of a given adaptation action. For example, Dane County, WI, included the following four actions—all of which were tagged as research and monitoring actions: (1) identify private wells most at risk of contamination from flooding, (2) model potential flood impacts and impact zones, (3) identify immediately available flood prevention methods, and (4) ensure that land the county owns, or has enforcement authority over, is not contributing to runoff pollution.

Practice and behavior (e.g., changing operations and maintenance schedules, opening cooling centers, implementing the best management practices) and planning actions (e.g.,

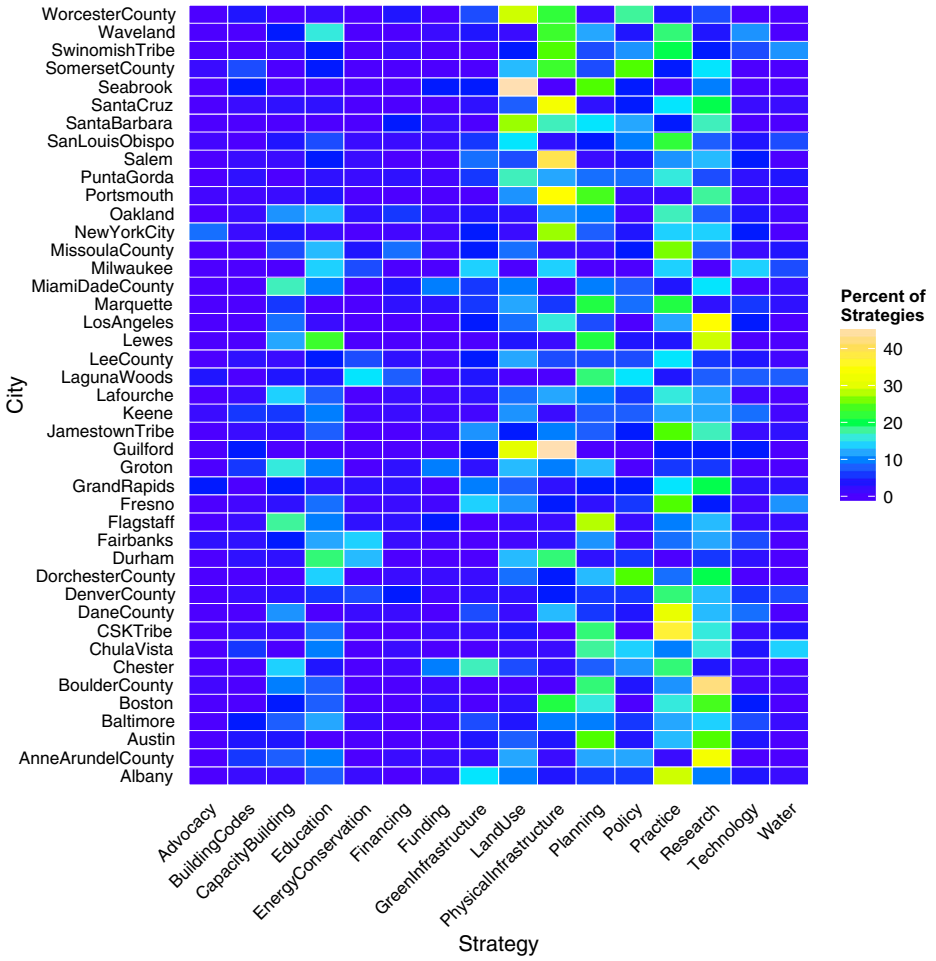

Fig. 2 The distribution of actions across action types for each plan in the sample. If an action type makes up a large percent of the actions in a plan, it is lighter in color

creating new or updating existing plans) were found in 41 of the 43 plans analyzed. *Land use* actions (e.g., transfer of development rights, no-build policies) were also prevalent, having been identified in 40 of the 43 plans. The least common type of adaptation action found across all of the plans was *advocacy*, which was found in only 11 of the 43 plans analyzed. Energy conservation (found in 19 of the 43 plans), water conservation (22 out of 43), and greenhouse gas mitigation actions (22 out of 43) were also found in relatively few plans.

Of the 3375 actions identified and categorized, the most common type by count was practice and behavior (594 actions, ~18% of actions, Fig. 3), followed by research and monitoring (498 actions, ~15% of actions) and physical infrastructure (459 actions, ~14% of actions). The least common type of adaptation action was advocacy (~1% of actions; New York City had 28 of the 44 advocacy actions identified). Funding, water conservation, financing, building codes and engineering design standards, and energy conservation were also infrequent, combined, making up less than 13% of all actions identified across the plans in our sample (Fig. 3).

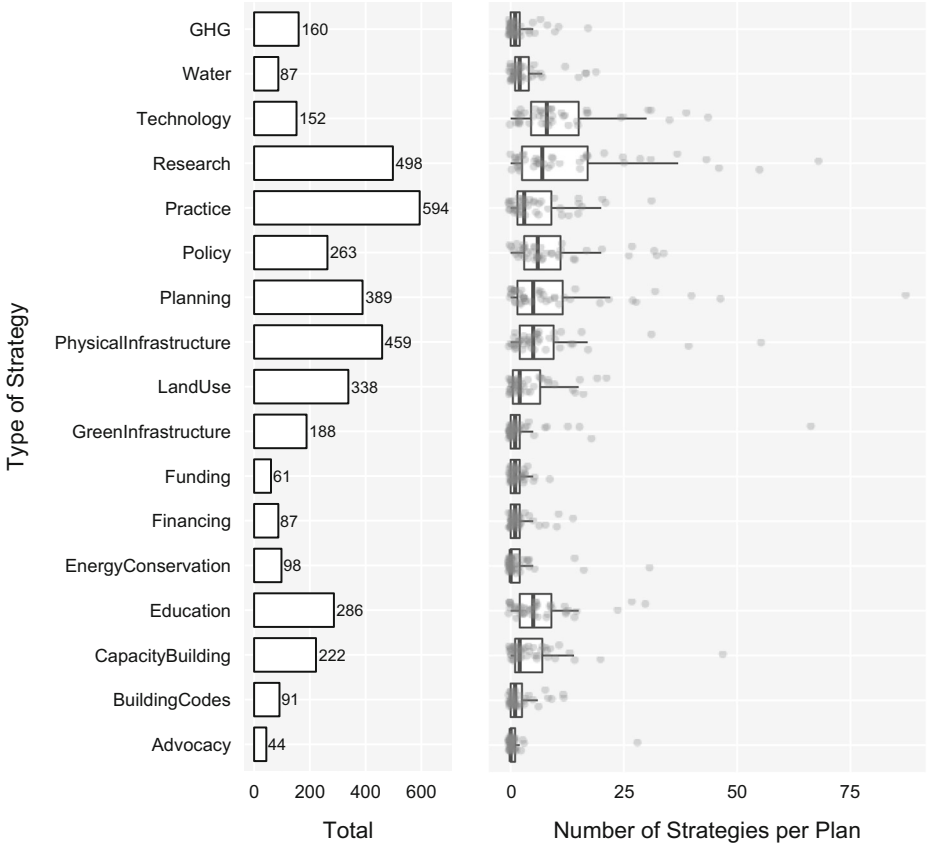

Fig. 3 Total number of actions categorized by strategy type and the average number of times each strategy occurred per plan. The *left panel* shows the total number of actions categorized by strategy type across the sample. The *right panel* depicts the number of times, on average, each strategy type occurred in the plans. Each point represents a plan in the sample (*right panel*)

Several types of actions were also commonly found together. For example, all plans that include a building code action also had actions related to land use. All plans that include an action related to financing also had planning actions. In addition, all plans that included actions focused on energy conservation also contained technology actions.

3.2 Climate impacts and adaptation actions

Most adaptation plans identified the same climate impacts as discussed in their corresponding regional chapter of the National Climate Assessment. However, 13 coastal communities focused exclusively on impacts related to sea level rise, such as inundation, erosion, and storm surge. For example, Miami-Dade County, FL, Santa Barbara, CA, and Anne Arundel County, MD, focused exclusively on sea level rise, omitting rising temperatures, extreme heat, and changing precipitation patterns. While plans that focus on coastal impacts explore the implications for numerous sectors such as public health, water supply, and infrastructure, ignoring other changes may leave communities unaware of and unprepared for other projected climate impacts.

Twenty-eight out of the 43 plans (66%) linked actions to possible future climate impacts or goals. This connection, however, was often broad, which made it impossible to connect individual adaptation actions to climate impacts. Fresno County, CA, for example, organizes adaptation actions into eight sector-based categories: (1) agriculture, (2) freshwater aquatic and riparian systems, (3) governance and planning, (4) health and emergency preparedness, (5) infrastructure, (6) valley floor grasslands and semi-desert, (7) water resources and infrastructure, and (8) woodlands and forests. For each sector, the plan identifies climate impacts; agriculture, for example, will be affected by rising temperatures, drought, and an increase in heavy downpours. Because each sector will be affected by multiple climate change impacts, it can be difficult to connect actions back to climate impacts. Many of the plans in the sample follow this approach, identifying high-level climate impacts and then organizing adaptation actions by sector. The sectors also vary considerably between plans. Grand Rapids, MI, organizes actions into broad social, environmental, and economic sectors. Baltimore uses infrastructure, natural systems, and public services. Denver uses building and energy, food and agriculture, health and human services, land use and transportation, and urban natural resources.

Conversely, New York City's plan, *a stronger, more resilient New York*, links actions to specific neighborhoods. To do this, the plan begins each chapter by identifying the specific climate impacts likely to affect a given neighborhood and then proposes actions for each area, but it does not specify which adaptation actions are connected to specific impacts. In this case, the action "implement planned upgrades to vulnerable city-owned, industrial properties" falls within the Brooklyn Queens-Waterfront chapter, where the major regional risks are identified as storm surge, sea level rise, increased precipitation, heavy downpour, and heat wave; many of which may threaten industrial properties. Portsmouth, NH, similarly proposes different actions for planning subareas and even detail actions for specific streets.

Ultimately, adaptation plans in the sample rarely and unevenly connect adaptation actions to the specific climate-related impacts they are intended to address. Exceptions exist in the case of Santa Barbara, CA, and Waveland, MS. For example, in its adaptation plan, *City of Santa Barbara Sea Level Rise Vulnerability Study*, Santa Barbara identifies the action, "develop retrofit or retreat plans for existing infrastructure subject to future inundation", which is specifically targeted at inundation caused by sea level rise. Similarly, Waveland, MS's *Local*

Hazard Mitigation Plan identifies the action, "provide an annual pre-hurricane season workshop and exercise for elected officials and emergency operations staff" to specifically address hurricane-related risks.

Because plans in the sample rarely connected adaptation actions to climate impacts, it is unclear whether the actions proposed in the plans correspond to the theoretical types of actions that the literature recommends communities implement based on projected impacts. We were, however, able to determine if the types of actions recommended in the literature (Table 1) were present in each of the plans for which a given climate impact was discussed as a current or future area of concern. To do this, we reviewed all of the climate impacts discussed within each plan, compared those to the impacts discussed in the relevant regional chapter of the 2014 US National Climate Assessment (Table 3), and then looked at the theoretical actions proposed to combat projected impacts (per Table 1).

Results showed that, in general, communities are including the types of adaptation actions proposed in the literature to address relevant climate impacts. Exceptions include a lack of building code actions: building code actions do not appear in 35% of plans that identify sea level rise as an issue, 40% that identify extreme precipitation as an issue, 40% that identify wildfires as an issue, 43% that identify storm surge as an issue, 44% that identify hurricanes and coastal storms as an issue, and 38% that identify extreme wind as an issue. Other gaps include a dearth of green infrastructure actions in plans where sea level rise, drought, or heat was identified as an issue of major concern; 27, 29, and 35% of the plans identifying these respective impacts omitted green infrastructure actions. Additionally, 33% of plans that identified drought as an issue of concern did not include water conservation actions.

3.3 Implementation guidance

Although adaptation plans in the sample include a large number and multiple types of actions, the limited attention to implementation raises questions about whether the proposed actions will translate into real-world projects. Results showed that many of the plans lack details that may be important for implementation; for example, only 51% of the plans in the sample discuss co-benefits. Cost is also rarely discussed; 44% of plans mention that the cost of inaction would be greater than the cost of preparing for climate change, but only 16% of plans provide the cost associated with implementing each identified action (Fig. 4).

Overall, plans perform poorly on all of the implementation and monitoring metrics. On average, plans within the sample contained only five of the 16 metrics deemed important in the literature to support implementation. Only two plans in the sample, Baltimore, MD, and Waveland, MS, contained over 80% of the implementation metrics. Plans for Grand Rapids, MI, and Milwaukee, WI, had none of the implementation metrics, and seven plans (Oakland, CA; Dane County, WI; Fairbanks, AK; Santa Barbara, CA; Austin, TX; Worcester County, MD; and Salem, MA) contained only one of the 16 implementation metrics.

The most common implementation related information captured in plans was *mainstreaming*, the integration of climate adaptation into other sector policies or plans (Friend et al. 2013), which was found in 86% (36 of 43) of plans (Fig. 4). These plans commonly provide specific guidance on how to integrate climate-related considerations into other plans. No other implementation metrics were present in more than half of the plans. The least common implementation metrics were evaluation methods and metrics, which are intended to provide guidance on how to measure the implementation progress of the plan.

Table 3 This table indicates the number of adaptation plans in each of the National Climate Assessment regions missing a given adaptation strategy type. The number in parenthesis below each of the NCA regions listed in the header represents the number of plans in the sample from each region. In each of the remaining boxes, the total number of plans that do not have a given strategy are identified, followed by the percentage of plans within each region that omit that given strategy in parenthesis. Note: Hawaii was not included as a region because no plans in our sample are from Hawaii. In addition, the NCA regions, rural communities, and coasts were not included as separate categories because using this classification would cause duplication within the data. As such, only seven of the ten 2014 NCA regions were used for categorizing plans within our sample

	NCA [1] region						
	Alaska (1)	Great Plains (5)	Midwest (4)	Northeast (17)	Northwest (2)	Southeast (5)	Southwest (9)
Advocacy	0 (0%)	4 (80%)	3 (75%)	12 (70.5-%)	2 (100%)	4 (80%)	7 (78%)
Building codes and engineering design standards	0 (0%)	2 (40%)	4 (100%)	4 (24%)	1 (50%)	2 (40%)	4 (44%)
Capacity building	0 (0%)	0 (0%)	1 (25%)	5 (30%)	0 (0%)	0 (0%)	2 (22%)
Education	0 (0%)	1 (20%)	2 (50%)	2 (12%)	0 (0%)	0 (0%)	1 (11%)
Energy conservation	0 (0%)	3 (60%)	1 (25%)	11 (64%)	2 (100%)	3 (60%)	4 (44%)
Financing	0 (0%)	3 (60%)	1 (25%)	9 (53%)	1 (50%)	1 (20%)	2 (22%)
Funding	0 (0%)	1 (20%)	3 (75%)	7 (41%)	1 (50%)	0 (0%)	4 (44%)
Green infrastructure	1 (10-0%)	1 (20%)	0 (0%)	5 (30%)	1 (50%)	0 (0%)	3 (33%)
Land use	0 (0%)	1 (20%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)	1 (11%)
Physical infrastructure	0 (0%)	2 (40%)	0 (0%)	1 (6%)	0 (0%)	1 (20%)	1 (11%)
Planning	0 (0%)	0 (0%)	1 (25%)	1 (6%)	0 (0%)	0 (0%)	0 (0%)
Policy	0 (0%)	1 (20%)	1 (25%)	3 (18%)	0 (0%)	0 (0%)	1 (11%)
Practice and behavior	0 (0%)	0 (0%)	0 (0%)	2 (12%)	0 (0%)	0 (0%)	0 (0%)
Research and monitoring	0 (0%)	0 (0%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Technology	0 (0%)	0 (0%)	0 (0%)	7 (41%)	0 (0%)	1 (20%)	1 (11%)
Water conservation	1 (10-0%)	1 (20%)	1 (25%)	14 (82.4-%)	0 (0%)	2 (40%)	1 (11%)
Other GHG	0 (0%)	1 (20%)	2 (50%)	10 (59%)	2 (100%)	1 (20%)	5 (56%)

Also infrequent across the plans was any discussion regarding when and how to report on plan implementation and update the plan (Fig. 4).

4 Discussion

The variation in the types of actions included in plans indicates that communities have taken different approaches to planning for climate change. While this variation does limit one's ability to analyze and compare plans, it also suggests that adaptation plans are being tailored to

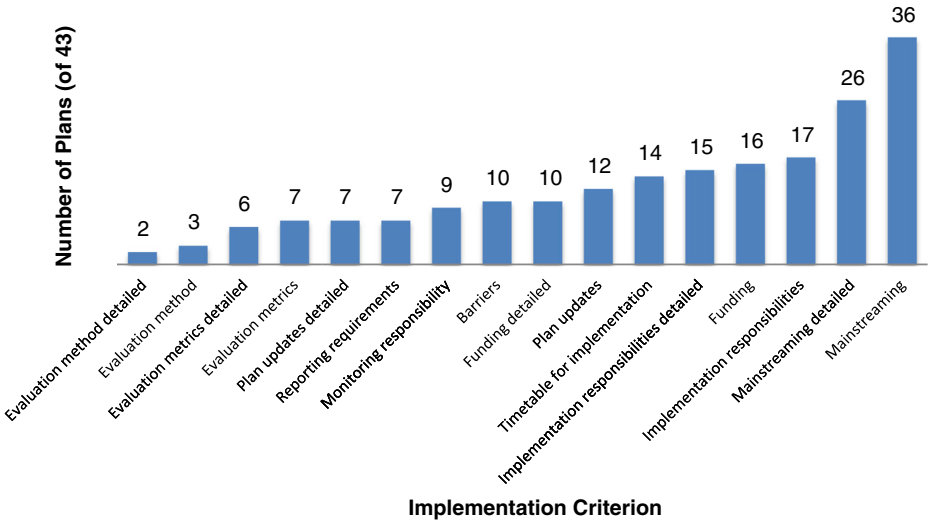

Fig. 4 Number of plans containing each of the implementation criterion assessed

the local context. Rather than just identifying regional climate impacts and proposing generic adaptation actions, communities are proposing actions to address their unique vulnerabilities and sectors of concern.

The breadth of action types included in plans may suggest that communities realize that they need a mixture of actions to prepare local services and sectors for climate-related impacts. On the other hand, the identification of a variety of actions may be a "hedging" strategy (Woodruff and Stults 2016) whereby communities are selecting a variety of actions in hopes that at least one of them will help reduce vulnerability. Regardless of the motivation, the variety of activities is promising, as it demonstrates that communities planning for climate change are looking to use their full range of authority to prepare.

Contrary to previous studies on local climate adaptation, results also suggest that communities are pursuing concrete or action-oriented actions as opposed to just capacity building actions. This is true even if research and monitoring, planning, advocacy, and education are grouped with capacity building to mirror the definition of capacity building presented by Tompkins et al. (2010). Doing this, we found that 1439 of the 3375 actions (just under 43%) are what Tompkins et al. consider capacity building. Conversely, the remaining 1935 (57%) are non-capacity building actions, which, if implemented, could result in direct reductions in vulnerability. The prevalence of land use actions (338 total actions, 10%), which the hazard mitigation literature has highlighted as the most effective method for reducing vulnerability (Burby et al. 2000), is also encouraging. This move towards more concrete adaptation actions suggests that there is growing awareness of both the types of actions available to local governments and the need to prioritize actions that can result in direct reductions in vulnerability.

Some adaptation actions, however, are still not widely used. For example, advocacy actions are included in only 11 of the 43 plans, but advocacy may be an important strategy for local governments to effect change. Local governments frequently cite federal and state laws and lack of authority as barriers to adaptation (Eisenack et al. 2014; Ekstrom and Moser 2014).

Given that local governments have little direct ability to influence these policies, advocacy can be an important tool to ameliorate or lessen these barriers.

The lack of greenhouse gas reduction actions is not surprising given that all plans in our sample focus exclusive on adapting to climate change. What is surprising, however, is the dearth of water conservation and energy conservation strategies; both of which are frequently touted as being win-win actions by helping communities both adapt and mitigate. The lack of emphases on these two strategies may indicate that communities are not fully considering the array of co-benefits associated with proposed adaptive actions. This possibility is further substantiated by the lack of discussion regarding the co-benefits of proposed actions across all plans in our sample (only 50% discuss the co-benefits of some proposed actions).

Findings from this analysis also show that communities are, broadly, including the types of actions one would expect based on their projected regional changes in climate. The exceptions, however, are a lack of building codes and green infrastructure actions within communities likely to face sea level rise, storm surge, coastal storms, wildfire, and extreme wind for building codes and sea level rise, drought, and heat waves for green infrastructure. The lack of building codes may be explained by the fact that, in many states, local governments do not have the authority to change or adopt different building codes. In these cases, local governments may be opting to use different types of actions to enhance the resilience of buildings and infrastructure, such as land use actions that limit development in disaster-prone regions. Conversely, we posit that communities may not be aware of how building codes can help address climate-related impacts such as wildfire or extreme heat.

Similarly, green infrastructure actions have traditionally been associated with stormwater management. Only recently has the potential of green infrastructure to address heat and air quality been explored (Larsen 2015). While the green infrastructure actions identified suggest that green infrastructure is being used to address multiple impacts, some communities may still not be aware of the multiple benefits associated with green infrastructure, which could explain why it is not being prioritized. More research is needed, however, to confirm if this is true in practice.

Our finding that there is rarely a direct connection between proposed actions and projected community impacts may suggest that communities are selecting actions that are viable across a range of projected changes in climate. Conversely, this finding may suggest that there is a disconnect in the planning process between vulnerability identification and adaptation action selection. Regardless of the rationale, the disconnect between actions and projected impacts may stymie future efforts to evaluate the efficacy of proposed actions. Specifically, without knowing what types of actions are meant to address what types of impacts, prioritizing actions for implementation and then evaluating the effectiveness of those actions will be a challenge.

Another potential challenge is that communities appear to be organizing their actions based on sectors (e.g., transportation, buildings). While this structure is strategic in that it may mirror the organization of the local government, if actions are being selected for a specific sector without consideration for how they could impact (positively or negatively) other sectors, there is a strong likelihood that actions will at best be less effective than if they were coordinated across sectors and, at worst, maladaptive (Barnett and O'Neill 2010). Since a discussion of the co-benefits of actions was largely missing from our sample, there is a reason to suspect that proposed actions are primarily included for their viability in a specific sector or system. This may mean that system-wide or coupled-system strategies are not yet

being considered in these first generation climate adaptation plans. However, more research is needed to understand if this is indeed true.

In regard to the lack of implementation criteria, findings from this analysis are in alignment with the previous plan evaluation studies (Berke et al. 2015; Lyles et al. 2014). Overall, the adaptation plans in the sample rarely included details that are theorized to be important in motivating implementation of plans, such as implementation responsibilities (40% of plans), timetables for implementation (33% of plans), and funding sources to support action implementation (23% of plans).

In addition to weak implementation details, plans also have weak monitoring components. To address the uncertainty associated with knowing exactly what future climate conditions will be, the adaptation literature emphasizes the need for iterative and flexible planning approaches that incorporate new information and lessons learned into future adaptation efforts (Quay 2010). The omission of evaluation metrics and timelines for updating the plan raises additional questions about how flexible these plans are to changing climatic conditions.

The finding that most plans emphasize mainstreaming, however, is a positive sign as it indicates that most communities realize the need to embed climate considerations into other dominant planning domains and decision-making processes. While there has been some discussion within the literature about the value of mainstreaming (e.g., Bierbaum et al. 2013; Friend et al. 2013), the fact that these communities have stand alone adaptation plans which can serve as their overarching adaptation guide and are simultaneously looking to embed climate change into other planning processes may be a sign that adaptation planning is becoming more common place (or is about to) within traditional types of local government planning. To test the extent to which this is true, other planning domains such as comprehensive and master planning, water resource planning, and hazard mitigation planning should be evaluated to determine the degree to which climate considerations are being integrated.

5 Conclusion

Using an inductive approach to categorize actions, this paper identified the actions in 43 stand alone, local climate adaptation plans in the US to better understand what actions local communities are prioritizing to address projected climate impacts. In total, 3375 discrete actions were identified and analyzed. On average, local adaptation plans include 93 actions from 12 of the 17 types profiled (median of 54). This breadth of actions suggests that communities are using their full range of authority to prepare for climate change. The number of action-oriented, concrete strategies included in plans (as opposed to those focusing solely on capacity building) also suggests that there is growing awareness of the need to implement a variety of actions to reduce place-based vulnerability. Moreover, adaptation plans appear to include the type of actions recommended in the literature to address their projected climate impacts. These results suggest that adaptation planning is being tailored to local conditions and needs.

There is, however, notable room for improvement. Limited details about actions, such as co-benefits and cost, suggest that communities have not fully considered what actions are feasible or effective. Moreover, the disconnect between future vulnerabilities and selected actions makes it hard to both determine if the most appropriate adaptation actions are being

prioritized while also limiting the ability of the local community to evaluate the effectiveness and efficacy of actions once they have been implemented.

These missing details may reflect the fact that many communities are still in the early stages of the adaptation cycle. Weak implementation guidance further demonstrates the limited progress communities have made in translating plans into action and the challenges they are facing in moving forward in the adaptation cycle. To ensure that communities progress from planning to implementation, greater attention must be placed on which actions are effective at reducing vulnerability, how communities can build political support for those actions, and how they can be funded.

Going forward, significant research opportunities exist around engaging with stakeholders to understand not only what adaptation actions get implemented but also why and how. This includes exploring the effectiveness of implemented actions, both in quantitative and qualitative terms, and assisting local practitioners with building upon existing and creating new approaches for monitoring climate adaptation activities. Mechanisms also need to be created for the sharing of successes and, perhaps more importantly, failures between practitioner communities and between practitioners and scholars. Finally, metrics for evaluating the effectiveness and efficiency of adaptation actions need to co-develop with practitioners to ensure they are both scientifically rigorous and appropriate given the local socio-political environment.

While this research focused on the US, these findings are consistent with a global shift from focusing on capacity building to the selection of concrete vulnerability reducing actions. The challenge in transitioning from planning to implementation is also shared by governments across the globe and scales. Moving from plan to implementation requires governments to shift from exploring what is necessary to what is effective and possible. Partnerships with researchers, boundary organizations, businesses, state and federal agencies, and local stakeholders will be essential in order to achieve the goals established in the first generation of climate adaptation plans. To aid future communities in their climate adaptation planning, we have made all 3375 actions identified during this analysis publicly available.[2] We sincerely hope that both scholars and practitioners use this information to help build the next generation of climate adaptation plans and, more importantly, as fodder for implementing adaptation actions that help us move towards creating more resilient and just local communities.

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Compliance with ethical standards

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[2] Data from this analysis can be found at https://figshare.com/articles/Content_Analysis_of_U_S_Local_Adaptation_Plans_xlsx/3843444.

Appendix 1: Initial metrics included by the authors in the first phase of coding within the "strategies" principle

This table summarizes all of the criteria included by the authors within the strategies principle. Column one lists the names of the individual criteria. All criteria are grouped into two categories: those that are specific types of adaptation strategies and those that help justify the need for adaptation strategy implementation. Column two briefly describes each criterion, and column three presents the percentage of plans within our sample that included the criterion.

Criterion	Description	Percent plans (%)
Type of adaptation strategy proposed		
Capacity building	The plan includes capacity building strategies. Capacity building is developing human resources, institutions, and communities, equipping them with the capability to adapt.	84
Advocacy	The plan includes advocacy strategies. Advocacy includes encouraging regional and state agencies to have adaptation-appropriate strategies.	25
General strategies	The plan includes generic adaptation strategies, which are strategies not specific enough to be classified in another category.	91
Information and awareness	The plan includes information and awareness strategies, which are strategies focused on increasing public knowledge.	84
Research and monitoring	The plan includes research or monitoring strategies, which are those that focus on gathering information and creating reports, maps, or models; monitoring includes observation or repeated measurements over time.	95
Planning	The plan includes planning-related strategies, which include strategies that incorporate understanding of climate science, impacts, vulnerability, and risk into government and institutional planning process, efforts, or existing initiatives.	91
Practice and behavior	The plan includes strategies to change practice and behavior. Practice and behavior strategies revise or expand practices and on-the-ground behavior that affect resilience.	95
Policy and legislation	The plan includes policy and legislation strategies aimed at preparing for climate change.	80
Physical infrastructure	The plan includes physical infrastructure strategies to prepare for climate change.	82
Building codes and engineering design standards	The plan includes strategies to improve physical infrastructure's response to changing climate through improved standards or engineering.	70
Green infrastructure	The plan includes green infrastructure strategies aimed at providing protection from climate hazards.	64

Criterion	Description	Percent plans (%)
Land use	The plan includes land use strategies focused on preparing for climate change.	82
Conservation	The plan includes conservation strategies to preserve biodiversity and protect open space under a changing climate.	66
Financing	The plan includes financing or insurance strategies to prepare for future climate changes.	55
Technology	The plan includes technology strategies.	66
Justification for the adaptation strategies		
Prioritized actions	The plan prioritizes adaptation strategies.	34
Prioritized strategies detailed	The plan prioritizes adaptation strategies and describes how strategies were ranked.	20
Specific adaptation strategies	The plan includes strategies that are linked to specific impacts.	55
Cost	The plan estimates the cost of implementing specific adaptation actions.	30
Cost detailed	The plan identifies the cost of implementing each adaptation strategy.	16
Cost of inaction	The plan states that taking action to adapt to climate change costs less than not acting.	43
Cost of inaction detailed	The plan provides specific dollar figures on the cost of inaction versus adaptation.	30
Co-benefits	The plan identifies co-benefits associated with taking adaptation action.	50

Appendix 2: Initial metrics included by the authors in the first phase of coding within the "implementation and monitoring" principle

This table summarizes all of the criteria included by the authors within the implementation and monitoring principle. Criteria are grouped into two categories: those that support implementation and those that support monitoring. Column one lists the names of the individual criteria, column two briefly describes each criterion, and column three presents the percentage of plans within our sample that included the criterion.

Criterion	Description	% plans
Implementation metrics		
Timetable for implementation	Provides a timetable for when each action will be implemented	32
Implementation responsibilities	Assigns responsibility for policies broadly to organizations or agencies	39
Implementation responsibilities detailed	Assigns responsibility for the implementation of each strategy	34
Funding (need for)	Describes the *need* for funding sources to implement the plan	36

Criterion	Description	% plans
Potential funding sources detailed	Clearly describes potential funding sources and associates them with particular strategies	23
Mainstreaming	Discusses mainstreaming climate change adaptation, mainstreaming refers to the integration of climate adaptation into other sector policies or plans	84
Mainstreaming detailed	Identifies specific plans and programs as opportunities for mainstreaming, mainstreaming refers to the integration of climate adaptation into other sector policies or plans	61
Barriers	Mentions barriers to climate adaptation	23
Monitoring metrics		
Reporting requirements	Includes requirements for the regular reporting of implementation progress	16
Monitoring responsibility	Mentions assignment of responsibility for monitoring	20
Evaluation method	Establishes a process to evaluate the plan	7
Evaluation method detailed	Describes when analyses of progress toward objectives will take place and how results will be used	5
Evaluation metrics	Mentions how to measure progress towards implementing strategies	16
Evaluation metrics detailed	Mentions how to measure progress towards implementing each strategy identified in the plan	14
Plan updates	Mentions need for updates	27
Plan updates detailed	Includes timetable for updating plan	16

Appendix 3: List of plans included in our analysis

List of communities with an adaptation plan (left column) and name of the plan (right column) included in our analysis.

Community	Plan title
Albany, NY	Albany Climate Change: Vulnerability Assessment and Adaptation Plan
Anne Arundel County MD	Sea Level Rise Strategic Plan: Anne Arundel County
Austin, TX	Toward a Climate-Resilient Austin
Baltimore, MD	Disaster Preparedness and Planning Project: Combined All Hazards Mitigation and Climate Adaptation Plan
Boston, MA	Climate Ready Boston: Municipal Vulnerability to Climate Change
Boulder County, CO	Boulder County Climate Change Preparedness Plan

Community	Plan title
Chester, PA	The City of Chester Vision 2020: Climate Adaptation Planning Elements
Chula Vista, CA	Climate Adaptation Strategies: Implementation Plans
City and County of Denver, CO	City and County of Denver Climate Adaptation Plan
Confederated Salish and Kootenai Tribes, MT	Climate Change Strategic Plan
Dane County, WI	Climate Change and Emergency Preparedness
Dorchester County, MD	Sea Level Rise: Technical Guidance for Dorchester County
Durham, NH	Climate Adaptation Chapter: Developing Strategies to Protect Areas at Risk from Flooding due to Climate Change and Sea Level Rise
Fairbanks North Star Borough, AK	Interior Issues Council Climate Change Task Force: Preliminary Vulnerability Assessment Report
Flagstaff, AZ	City of Flagstaff Resiliency and Preparedness Study
Fresno County, CA	Integrated Strategies for a Vibrant and Sustainable Fresno County
Grand Rapids, MI	Grand Rapids Climate Resiliency Report
Groton, CT	Preparing for Climate Change in Groton, Connecticut: A Model Process for Communities in the Northeast
Guilford, CT	Town of Guilford Community Coastal Resilience Plan
Jamestown S'Klallam Tribe, WA	Climate Vulnerability Assessment and Adaptation Plan
Keene, NH	Adapting to Climate Change: Planning a Climate Resilient Community
Lafourche Parish, LA	The Lafourche Parish Comprehensive Resiliency Plan
Laguna Woods, CA	Climate Adaptation Plan
Lee County, FL	Lee County Climate Change Resiliency Strategy
Lewes, DE	The City of Lewes Hazard Mitigation and Climate Adaptation Action Plan
Los Angeles, CA	Sea Level Rise Vulnerability Study for the City of Los Angeles
Marquette, MI	Adapting to Climate Change and Variability
Miami-Dade County, FL	Second Report and Initial Recommendations: Presented to The Miami-Dade Board of County Commissioners
Milwaukee, WI	Wisconsin Initiative on Climate Change Impacts: Milwaukee Working Group Report
Missoula County, MT	Missoula County Climate Action: Creating a Resilient and Sustainable Community
New York City, NY	A Stronger, More Resilient New York
Oakland, CA	Community Based Climate Adaptation Planning: Case Study of Oakland, California
Portsmouth, NH	City of Portsmouth, New Hampshire's Coastal Resilience Initiative Climate Change Vulnerability Assessment and Adaptation Plan
Punta Gorda, FL	City of Punta Gorda Adaptation Plan
Salem, MA	Ready for Tomorrow: The City of Salem Climate Change Vulnerability Assessment and Adaptation Plan
San Luis Obispo (county), CA	Integrated Climate Change Adaptation Planning in San Luis Obispo County
Santa Barbara, CA	City of Santa Barbara Sea Level Rise Vulnerability Study

Community	Plan title
Santa Cruz (city), CA	City of Santa Cruz Climate Adaptation Plan: An Update to the 2007 Local Hazard Mitigation Plan 2012-2017
Seabrook, NH	Adaptation Strategies to Protect Areas of Increased Risk From Coastal Flooding Due to Climate Change
Somerset County, MD	Somerset County, Maryland: Rising Sea Level Guidance
Swinomish Tribe, WA	Swinomish Climate Change Initiative Climate Adaptation Action Plan
Waveland, MS	City of Waveland Local Hazard Mitigation Plan
Worcester County, MD	Sea Level Rise Response Strategy: Worcester County, Maryland

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