Report on the

NOAA Office of Education

Environmental Literacy Program

Community Resilience Education Theory of Change

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Foreword

Climate change is the most pressing issue of the century. Already, its impacts are testing our emotional, infrastructural, and societal tolerances. Damage from extreme weather and susceptibility to pandemics have increased and communities of color and poverty are bearing a disproportionate share of the burden. This report outlines how creating a more environmentally literate society can help us face climate change and other threats to build a safer, healthier, and more resilient future for people and the planet. It means rethinking everything we do, from how we produce and consume energy, food, and water to how we protect the planet's biodiversity.

Having worked in the environmental movement for more than three decades, I believe that environmental education provides a set of unique and vibrant tools to create a more just and sustainable future. It is a life-long process that informs and inspires, advances equity and inclusion, builds human capacity, influences attitudes, and galvanizes actions to create healthier communities and a healthier environment for all.

That is why I'm so excited about this report and theory of change from the NOAA Office of Education's Environmental Literacy Program. Using multiple disciplines, the theory of change underpinning the report shows the pathways through which environmental literacy leads to resilient communities, whose members are hopeful, motivated, and skilled in addressing the tough environmental and social issues of our time. It provides a conceptual framework for tracking how community resilience education leads to increased community engagement and civic action—tackling both climate change mitigation and adaptation, since both are equally important and urgent.

NOAA is a national leader in supporting environmental and scientific literacy. One of its outstanding contributions are the grants from the Environmental Literacy Program, which is the longest standing and most comprehensive national funding opportunity focused on environmental literacy. This report lays out in clear terms the overarching philosophy that is and will be guiding NOAA's Environmental Literacy Program. The report will help everyone working in the field to understand a number of critical concepts, from how to define environmental literacy to the relationships between environmental education, STEM, resilience, citizen science, and more. It also defines more than 100 outcomes for community resilience education.

I am impressed by the way the report builds on the expanding literature in environmental education. At the North American Association for Environmental Education (NAAEE), we are particularly proud that two of our seminal publications are cited in this report, the "Community Engagement: Guidelines for Excellence," which promote effective practice in the field, and "Developing a Framework for Assessing Environmental Literacy," which defines environmental literacy. We have been so honored to work with the NOAA Office of Education through our five-year eeBLUE partnership to increase environmental and science literacy among NOAA's partners and external networks. This report is one of the results of our partnership.

As the report highlights, “only when existing inequities and imbalances of power are addressed will communities truly be resilient.” Both the COVID-19 pandemic and climate change crisis reveal that we are only as strong as our most vulnerable members of our society. Our work needs to continue to prioritize equitable approaches in everything we do.

An exceptional team has pulled together the research and produced a thoughtful and compelling theory of change and report. I commend the authors, Genie Bey, Carrie McDougall, and Sarah Schoedinger; Louisa Koch, who oversees education at NOAA; and all the reviewers who offered their insights. I am confident that many audiences, from grantees to non-profit leaders to education professionals and decision makers, will find this work extremely valuable and thought-provoking.

Judy Braus
Executive Director
North American Association of Environmental Education (NAAEE)

Executive Summary

NOAA's Environmental Literacy Program (ELP) supports projects that both inspire and educate people to use Earth system science to increase ecosystem stewardship and resilience to extreme weather, climate change, and other environmental hazards (NOAA Education Strategic Plan, 2015-2035). In 2015, ELP grants shifted from focusing on climate change education to community resilience education.

This shift occurred in response to a need identified by ELP grantees to use approaches that are more solutions-oriented for educating, engaging, and empowering children, youth, and adults to tackle climate impacts and other environmental challenges. Resilience offered a framework that is locally focused, solutions oriented, and actionable. Since this shift occurred, the program has funded 22 community resilience education projects across the United States, testing approaches that target different audiences.

Community resilience education was not only a new area of investment for NOAA's Office of Education, but also an emerging field in education that required different ways of planning and implementing programs than previous approaches used in climate change and science education. Many lessons were being learned by ELP grantees and their peers who were working toward building community resilience through informal and formal education. At the same time, ELP staff were being asked to articulate how one would demonstrate that ELP-funded projects were contributing to achieving the stated goal of the funding program: to build the environmental literacy of children, youth and/or adults so they are knowledgeable of the ways in which their community can become more resilient to extreme weather events and/or other environmental hazards and become involved in achieving that resilience. The need to create a theory of change for the ELP's community resilience education grants became clear.

What Is a Theory of Change?

The ELP Community Resilience Education Theory of Change communicates the overarching philosophy guiding its grants program. It can also be used to inform project-level logic models, ensuring that a project's activities, outcomes, and goals are aligned with the ELP outcomes and goals articulated in this theory of change. Theories of change, much like logic models, are tools for planning, implementation, and evaluation of an initiative. They are broad in scope and are typically focused at the program level rather than on the individual project level. Following guidance from the United Kingdom Climate Impacts Programme's report Theory of Change approach to climate change adaptation programming (Bours, McGinn, and Pringle 2014), the

ELP Community Resilience Education Theory of Change includes: (1) a problem statement, wherein the challenge to be addressed is articulated fully; (2) an end goal, which is the "big picture" outcome toward which the program resources and activities are aimed; and (3) the pathways that will lead toward achieving that outcome. The end goal here is large in scope and it cannot be accomplished by NOAA or the ELP alone. Therefore, an intermediate goal that articulates how the ELP contributes to the end goal has also been written and is referred to as the ELP goal. Interventions provided by the agency and program show how both are working to address the challenges laid out in the problem statement to achieve the end goal.

Defining Resilience

The ELP acknowledges that the concept of resilience has been defined, researched, and debated across many academic disciplines, and has grown increasingly popular in recent years in research and policy discourse (Dubois and Krasny 2016; Meerow, Newell, and Stults 2016). For this theory of change, the definition of resilience used is the one put forth by the U.S. Global Change Research Program (USGCRP), "a capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment" (2020). It is important to note that this definition of resilience, like many others, is limited to a concept of "bouncing back" to a previous state that may be fundamentally unstable and unjust. In the theory of change that follows, this limitation has been attempted to be addressed by articulating an end goal that encompasses "bouncing forward", that is, transforming to a more equitable and sustainable future state (Figure 1).

Situating Community Resilience Education among NOAA's Other Resilience Investments

This theory of change demonstrates the ways in which ELP fills a gap in resilience-building approaches and the audiences engaged by those approaches. NOAA's other resilience investments are focused on creating and promoting the use of science-based information and training for adults to apply that information within the context of their professions. While building the capacity of adults to use this information in a professional context *is* essential, so is equipping community members with the environmental literacy necessary to make informed decisions about the place-based challenges they face *outside of a professional context*. When community members engage in informed decision making, the efforts of resilience practitioners and local or state officials engaged in building community resilience are further supported.

Purposes of This Theory of Change

The ELP's aim in creating this theory of change is to outline the conceptual framework for the ways in which community resilience education can lead to increased community engagement and civic action, ultimately leading to a healthier, more resilient, and equitable society. This theory of change will serve a suite of purposes:

1. To provide a visual representation of the overarching philosophy that guides the current focus of the ELP grants program, informing program evaluation and future funding announcements. The theory of change is a tool to communicate the program's purpose, audiences, and activities, as well as the assumptions, intended outcomes, and ultimate end goal of ELP investments.
2. To offer current and future ELP grantees a resource to understand how their local efforts contribute to a broader, national effort to increase resilience to extreme weather, climate change, and other environmental hazards.
3. To aggregate effective approaches and outcomes identified by grantees.
4. To articulate the value of education in community, city, state, and national efforts to build community resilience to extreme weather, climate change, and other environmental hazards.
5. To serve as a model for how environmental literacy contributes to resilience that others working in the field of community resilience might use.

Intended Audiences

The intended audiences for this theory of change are NOAA colleagues; grantees; grantee partners; applicants; education professionals; resilience practitioners; and individuals from other local, state, and federal government agencies, environmental non-governmental organizations, and community, corporate, and private foundations.

Sources and Feedback

Numerous sources were consulted in the development of this theory of change. The community resilience education projects funded by the ELP served as the primary basis for the theory of change. Relevant theories of change from other programs were also consulted. An extensive review of published literature in related fields was conducted (see Section II). The concepts explored through the literature review form the basis for the set of assumptions that explain the relationship within and among the causal pathways of the ELP theory of change.

These summaries fall into six thematic clusters:

1. Resilience to Extreme Weather, Climate Change, and Other Environmental Hazards;
2. Science, Technology, Engineering, and Math (STEM) Education, Environmental Education, Social Studies Education, and Related Literacies;
3. Connecting Environmental Literacy and Social-Ecological Resilience;
4. Active Learning, Social Learning, and Co-Production of Knowledge;
5. Equitable Resilience and Climate Justice; and
6. Empowering Agents of Change.

Just as important was the input received throughout the development process. NOAA leadership and staff in NOAA's Office of Education, the NOAA Education Council, and NOAA experts in climate resilience and education provided feedback. Stakeholder input was gathered at the 2019 NOAA ELP Community Resilience Education Grantee Workshop and the 2019 American Geophysical Union Fall Meeting.

Characteristics of NOAA's ELP Community Resilience Education Projects

Community resilience education programs differ from other science or environmental education programs in that they have different objectives, novel methods, and rely heavily on strategic partnerships (e.g., local/state government agencies and community-based organizations). Recognizing the importance of peer-to-peer learning and sharing best practices in developing fields, ELP formed a community of practice among the ELP community resilience education grantees, their partners, and other resilience programs at NOAA. Collaboration within this group allows for identification of unique aspects of community resilience education projects and advances the field more rapidly. The concept of community resilience education has emerged from what the ELP community of practice learned collectively and has formed the basis of this theory of change. A definition of education as it pertains to community resilience to extreme weather, climate change, and other environmental hazards has also been generated:

> **Community resilience education:** Educational approaches that develop community-level environmental literacy to understand threats and implement solutions that build resilience to extreme weather, climate change, and other environmental hazards. Environmental literacy here includes the knowledge, skills, and confidence to: (1) reason about the ways that human and natural systems interact globally and locally, including the acknowledgement of disproportionately distributed vulnerabilities; (2) participate in civic processes; and (3) incorporate scientific information, cultural knowledge, and diverse community values when taking action to anticipate, prepare for, respond to, and

recover from environmental hazards, including mitigating and adapting to climate change.

The effort to articulate a theory of change for community resilience education also motivated program staff to identify the characteristics that make NOAA's ELP community resilience education projects different from previous investments. These characteristics are summarized on the facing page.

NOAA's ELP Resilience Education Projects...

1. Build collective environmental literacy
2. Focus on current and future place-based environmental hazards
3. Support local and state government resilience efforts through use of resilience plans and creation of new partnerships between education institutions and local or state government offices charged with resilience planning
4. Incorporate scientific information, including NOAA's resilience assets
5. Explore and implement community-scale solutions to improve community resilience
6. Integrate social, historical, economic, and ecological factors into teaching about the ways human and natural systems interact
7. Integrate the history, culture, and lived experiences of diverse community members
8. Promote equitable and inclusive resilience planning that ensures historically marginalized voices are incorporated in the process and contributes to overall community health
9. Use active learning
10. Use social learning approaches that cultivate social cohesion
11. Facilitate opportunities for civic engagement and enable audiences to take action in their communities
12. Inspire hope and empower agents of change
13. Build capacity within education systems to address community resilience
14. Develop successful community resilience education approaches that contribute to the ELP Community of Practice

Figure 1. This illustration of the ELP Vision of A Resilient Community depicts several key aspects of the ELP Community Resilience Education Theory of Change. The ELP and end goals are brought to life through this portrayal of the future. The illustration also depicts all of the major institutional players, such as museums, aquariums, K-12 schools, universities and other educational and community-based organizations; the audiences; and the key approaches that have been identified as effective in using education to build community resilience. Children, youth, and adults are learning together and are directly engaged in activities that improve the resilience of their community.

Introducing the ELP Community Resilience Education Theory of Change

The complete theory of change is contained in Section IV of this report. It includes the full text of the problem statement; agency and program-level interventions; the ELP goal; the end goal; as well as a "Pathway to Change" that contains the major outcomes from the six causal pathways and how they relate to the problem statement, interventions, ELP goal, and end goal. In addition, causal pathways describing the short-, mid-, and long-term outcomes are included. The causal pathways are based on the approaches and outcomes from the ELP-funded community resilience education projects and assumptions gleaned from the literature review discussed in Section II of this report. The causal pathways are as follows:

- Causal Pathway 1: ELP Community of Practice Advances Effective Approaches
- Causal Pathway 2: Resilience Planning and Policies Integrate Education
- Causal Pathway 3: Active Learning Enables Community Engagement in Civic Processes

- Causal Pathway 4: Understanding Cultural and Historical Context of Place Builds Social Cohesion
- Causal Pathway 5: Student-driven Action Projects Implement Resilience Measures
- Causal Pathway 6: Youth Summits Empower Agents of Change

The six causal pathways in this theory of change are not the only means to achieve community resilience through education, nor are they meant to be prescriptive. Successful projects may achieve outcomes in several different causal pathways and not all projects will achieve all of the long-term goals in a pathway. Most of the short- and mid-term outcomes encompassed in these pathways are already occurring in existing projects, whereas the long-term outcomes are aspirational and may occur with more effort (i.e., more than one project) and over a longer time period. Community resilience education projects can be evaluated based on pathway outcomes, although impact evaluation would likely include outcomes specific to project goals and context. As additional investments in this area are made and the program evolves, additional outcomes or causal pathways may be developed. Other institutions beyond those funded through NOAA's ELP may identify other causal pathways that contribute to the end goal articulated in this theory of change.

The Community Resilience Education Theory of Change is a living document that will be updated regularly to reflect progress made by the ELP, as well as other contributions to the field of community resilience education.

Section I: Program History and Evolution to Community Resilience Education

Introduction

NOAA's Environmental Literacy Program (ELP) supports projects that both inspire and educate people to use Earth system science to increase ecosystem stewardship and resilience to extreme weather, climate change, and other environmental hazards (NOAA Education Strategic Plan, 2015-2035). Since the ELP's inception in 2005, grants offered through this program have supported both formal (K-12) and informal education initiatives that serve NOAA's mission of science, service, and stewardship. As outlined in NOAA's 2015-2035 Education Strategic Plan, "[f]or society to become more resilient, individuals should have the ability to understand scientific processes, consider uncertainty, and reason about the ways that human and natural systems interact. Therefore, it is not enough for NOAA to research Earth systems; NOAA must also empower the Nation to use this information to support healthy ecosystems, communities, and economies." This reasoning lays the foundation for the critical role that education plays to achieve NOAA's mission.

The ELP has developed this Community Resilience Education Theory of Change to communicate the overarching philosophy guiding its grants program. It can also be used to inform project-level logic models, ensuring that a project's activities, outcomes, and goals are aligned with the ELP outcomes and goals articulated in this theory of change. Theories of change, much like logic models, are tools for planning, implementation, and evaluation of an initiative. They are broad in scope and are typically focused at the program level rather than on the individual project level. The United Kingdom Climate Impacts Programme's report *Theory of Change approach to climate change adaptation programming* is a helpful guide on this topic, and was used in the development of the ELP's theory of change. This report describes a theory of change in this way:

> [Theory of change] approaches articulate an ultimate 'big picture' outcome, and then 'backwards map' the steps needed to achieve it. In other words, the stakeholders begin with defining the long-term goal, and work backwards in time up to the present, systematically laying out each step along a 'causal pathway.' For each step in the sequence, stakeholders outline clear indicators, thresholds, and assumptions. The end result is usually a diagram ('change map'), accompanied by a narrative. Theory of change is also an iterative process; in other words, the strategy would be reviewed regularly and modified to reflect emerging conditions and new knowledge (Bours, McGinn, and Pringle 2014, 2).

The UKCIP guidance was used with one exception: in lieu of articulating indicators and thresholds, this theory of change articulates different levels of outcomes.

Additionally, as part of the development of the theory of change, a definition for community resilience education has been created and is provided later in this report.

The Need for a Theory of Change

This theory of change demonstrates the ways in which the ELP fills a gap in resilience-building approaches and the audiences engaged by those approaches. NOAA's other resilience investments are focused on creating and promoting the use of science-based information and training for adults to apply that information within the context of their professions. While building the capacity of adults to use this information in a professional context *is* essential, so is equipping community members with the environmental literacy necessary to make informed decisions about the place-based challenges they face *outside of a professional context*. When community members engage in informed decision making, the efforts of resilience practitioners and local or state officials engaged in building community resilience are further supported. Finally, NOAA recognizes the importance of program evaluation and monitoring, and wanted to create a mechanism for tracking progress toward the ELP goal.

The ELP's aim in creating this theory of change is to outline the conceptual framework for the ways in which community resilience education can lead to increased community engagement and civic action, ultimately leading to a healthier, more resilient, and equitable society. This theory of change will serve a suite of purposes:

1. To provide a visual representation of the overarching philosophy that guides the current focus of the ELP grants program, informing program evaluation and future funding announcements. The theory of change is a tool to communicate the program's purpose, audiences, and activities, as well as the assumptions, intended outcomes, and ultimate end goal of ELP investments.
2. To offer current and future ELP grantees a resource to understand how their local efforts contribute to a broader, national effort to increase resilience to extreme weather, climate change, and other environmental hazards.
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5. To serve as a model for how environmental literacy contributes to resilience that others working in the field of community resilience might use.

The intended audiences for this theory of change are NOAA colleagues; grantees; grantee partners; applicants; education professionals; resilience practitioners; and individuals from other local, state, and federal government agencies, environmental non-governmental organizations, and community, corporate, and private foundations.

Numerous sources were consulted in the development of this theory of change. The community resilience education projects funded by ELP served as the primary basis for the theory of change. Relevant theories of change from other programs were consulted, including the American Association for the Advancement of Science Theory of Change for Public Engagement with Science (American Association for the Advancement of Science | Center for Public Engagement with Science & Technology 2016) and the aforementioned UKCIP Theory of Change approach to climate adaptation programming (Bours, McGinn, and Pringle 2014), as well as published literature in related fields. Input from NOAA staff and multiple stakeholders was incorporated throughout the development process. NOAA leadership and staff in NOAA's Office of Education, the NOAA Education Council, and NOAA experts in climate resilience and education provided feedback. Stakeholder input was also gathered at the 2019 NOAA ELP Community Resilience Education Grantee Workshop and the 2019 American Geophysical Union Fall Meeting.

Shifting Focus from Climate Change Education to Community Resilience Education

NOAA's ELP began focusing on building the climate literacy of children, youth, and adults in 2009. At the same time, Congress asked the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) to support climate education. Recognizing that no single institution, education sector, or federal agency is sufficient to support the nation's climate education needs, NOAA, NASA, and NSF formed the Tri-Agency Climate Education (TrACE) Collaborative and coordinated more than $110M of their investments in approximately 125 climate change education projects. This collaboration resulted in:

- An expanded research base on best practices in climate change education and communication and a common logic model;
- An active learning community focused on developing, implementing, and evaluating climate change education activities and programs;
- Infrastructure supporting networks of scientists, educators and others from academia, government, zoos and aquariums, and museums, who are involved in improving climate literacy among a diverse range of audiences; and

- Activities and products for use in climate change education and communication[1].

Between 2009 and 2014, when the TrACE Collaboration was most active, there was an emerging recognition from within the TrACE Collaboration community, as well as the wider climate literacy community[2], that increasing awareness of climate change and understanding of its causes was not sufficient to motivate audiences to take action to mitigate and adapt to climate impacts. Project evaluations indicated that even highly engaging science education projects that successfully built deep knowledge of the causes of climate change did not result in behavioral changes. Participants in these projects often expressed an interest in taking action, but they needed guidance on how to do so beyond household-level changes in behavior. The Ocean Project found similar results in studies of visitors to aquariums, and identified how youth can be powerful agents of change in their communities by engaging their peers and adults (The Ocean Project 2009; The Ocean Project 2011, 4). Additionally, the Yale Program on Climate Change Communication found that, while a majority of Americans believed climate change is happening, only a minority believed it would affect their lives directly (Yale Program on Climate Change Communication 2019).

By 2015, it had become clear that different approaches were needed to engage the public in stewardship and building resilience to environmental hazards at the community level. As a result, the focus of the ELP shifted from funding primarily climate literacy projects to funding K-12 and informal education projects focused on building community resilience to extreme weather, climate change, and other environmental hazards. These new approaches are solutions-oriented, locally focused, and engage, educate, and empower participants to take action individually and collectively. The first competition supporting this new program focus elicited a greater response than any previous ELP grant competition[3].

From 2015 to 2019, the ELP funded 22 community resilience education projects across the United States, its territories, and U.S.-based tribal communities. These projects serve rural, suburban, and urban audiences. The goal of these investments is to build environmental literacy of children, youth, and adults so they are knowledgeable of the ways in which their community can become more resilient to extreme weather, climate change, and other environmental hazards, and become involved in achieving community resilience. Education in this context does not include training for professionals working in the field of resilience, but it

[1] Learn more about these activities and products and the projects that created them in the TrACE Catalog at https://cleanet.org/trace/index.html.
[2] See the Climate Literacy and Energy Awareness Network at http://www.cleannet.org.
[3] These 22 projects came from a pool of 540 applications submitted through 3 separate competitions held between 2015 and 2018.

does include lifelong education that occurs within the formal (grades K-12) system and outside of it. There is no single ideal age audience to engage. Rather the audiences engaged will vary by community and the issue(s) being faced.

All ELP-funded projects focus on the most pertinent current and future environmental hazards of a particular place (or places), use local resilience plans[4], and support local and state government efforts to build resilience. They create new partnerships between education institutions and local and state government offices charged with resilience planning, and they also may involve non-governmental and community-based organizations working in communities. To develop an understanding of scientific concepts and the scientific process among participants, projects use NOAA's resilience assets and other scientific tools, such as the U.S. Climate Resilience Toolkit. Beyond natural science information, projects also incorporate social, cultural, historical, and economic factors as they develop participants' capacity to reason about the ways human and natural systems interact. They also engage participants in active and social learning to explore the impacts of extreme weather and climate change, as well as the inherent trade-offs associated with the different ways for addressing those impacts. Finally, these projects emphasize exploring and implementing community-scale solutions.

Defining Resilience

The ELP acknowledges that the concept of resilience has been defined, researched, and debated across many academic disciplines, and has grown increasingly popular in recent years in research and policy discourse around disaster preparedness and climate action planning (Dubois and Krasny 2016; Meerow, Newell, and Stults 2016). This rise in popularity can be attributed to resilience theory being highly applicable to complex social-ecological systems, especially with regard to climate change. While many definitions of resilience exist, the definition put forth by the U.S. Global Change Research Program (USGCRP) is most in line with the goal of the ELP. They define resilience as: "a capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment" (2020). It is important to note that this definition of resilience, like many others, is limited to a concept of "bouncing back" to a previous state that may be fundamentally unstable and unjust. In the theory of change that follows, this limitation has been attempted to be addressed by articulating an end goal that encompasses "bouncing forward", that is, transforming to a more equitable and sustainable future state.

[4] For the purposes of this theory of change, resilience plans may include climate action plans, climate adaptation plans, hazard mitigation plans, sustainability plans, climate resilience plans, among others.

Defining Community Resilience Education

As the ELP began funding projects focused on community resilience education, there was a realization that it was a nascent field that required different ways of planning and implementing programs. Community resilience education programs differ from other science or environmental education programs in that they have different objectives, novel methods, and rely heavily on strategic partnerships (e.g., local/state government agencies and community-based organizations). Recognizing the importance of peer-to-peer learning and sharing best practices in developing fields, the ELP formed a community of practice among the ELP community resilience education grantees, their partners, and other resilience programs at NOAA. Collaboration within this group allows for identification of unique aspects of community resilience education projects and advances the field more rapidly. The concept of community resilience education has emerged from what the ELP community of practice learned collectively and has formed the basis of this theory of change. A definition of education as it pertains to community resilience to extreme weather, climate change, and other environmental hazards has also been generated:

> Community resilience education: Educational approaches that develop community-level environmental literacy to understand threats and implement solutions that build resilience to extreme weather, climate change, and other environmental hazards. Environmental literacy here includes the knowledge, skills, and confidence to: (1) reason about the ways that human and natural systems interact globally and locally, including the acknowledgement of disproportionately distributed vulnerabilities; (2) participate in civic processes; and (3) incorporate scientific information, cultural knowledge, and diverse community values when taking action to anticipate, prepare for, respond to, and recover from environmental hazards, including mitigating and adapting to climate change.

Through the work of the grantees in this community and by examining other findings from similar efforts and relevant literature, the characteristics of effective community resilience education are being refined. The following concepts have emerged as critical to building community resilience through education:

1. Collective environmental literacy is essential. Not all individuals in a community must have the same level of environmental literacy, but there is a level of collectively held environmental literacy necessary to be resilient.
2. Cohesive social networks in a community build resilience. When individuals within a community learn from each other or together, bonds within the community are strengthened (Sharpe et al. 2018; NASEM 2019).

3. Equity and inclusion must be central to community resilience education. As communities understand how human and natural systems interact, it is essential that they also understand how vulnerabilities to environmental hazards are disproportionately distributed, and take approaches to address existing inequities (Matin, Forrester, and Ensor 2018; The Greenlining Institute 2019).
4. Policies are more robust when they reflect the values of society (Bozeman and Sarewitz 2011). For those values to manifest themselves, diverse community members need to contribute to policy deliberations and be civically engaged in creating healthier and stronger communities. However, there are many barriers, perceived and actual, to community members becoming civically active–skills and confidence first need to be improved, and pathways for community members to take action on climate change adaptation and mitigation need to be explicit and accessible.
5. Hope inspires action. One of the conundrums of teaching and learning about climate change is that the more one comes to understand the magnitude of the impacts and the complexity of the problem, the more likely they are to feel hopeless and unmotivated to take action (Doherty and Clayton 2011; Ojala 2012; Clayton, Manning, and Hodge 2014). For this reason, community resilience education needs to inspire hope by focusing on solutions and empowering community members to help develop and support the implementation of those solutions.

The Entire Education Sector Has a Role to Play

The concepts described above represent a set of broad and holistic approaches in which many disciplines are engaged and educational activities span a person's lifetime. Education is the primary means for building environmental literacy (Roth 1992). Therefore, the entire education sector has a role to play in achieving environmental literacy (United Nations Educational, Scientific, and Cultural Organization 1977, 12; Roth 1992, 35). K-12 schools can help lay the foundation for students to engage on these topics. Educators can serve as youth mentors and become experts in engaging students in local resilience issues. In particular, environmental educators, often operating outside of the K-12 arena, are uniquely situated to engage multiple stakeholders to address environmental, social, and economic challenges, and to explicitly connect communities to processes that enhance well-being (NAAEE 2017, 11). Informal education institutions, such as science centers, aquariums, and non-profit environmental or educational organizations, are often cited as trusted sources of science and conservation information (Spitzer and Fraser 2020). As such, they may serve as resilience hubs for their community to learn about and become engaged in these topics over a lifetime of learning

(Schubel et al. 2013; Hoffman 2020; Spitzer and Fraser 2020). Higher education can further strengthen the workforce pipeline to implement and respond to new policies and emerging practices to mitigate and adapt to extreme weather, climate change, and other environmental hazards. These institutions may also serve as research centers and translators of that research into practice. All of these educational institutions are well positioned to respond to the resilience needs of their local community, demonstrate effective resilience practices, and serve as important partners with local and state governments in achieving resilience.

Section II: Literature Review and Assumptions

The following section summarizes the literature that informed this theory of change, from the articulation of the problem statement to the characteristics critical to the success of community resilience education in achieving the goal of building resilience to extreme weather, climate change, and other environmental hazards. These summaries fall into six thematic clusters:

1. Resilience to Extreme Weather, Climate Change, and Other Environmental Hazards;
2. Science, Technology, Engineering, and Math (STEM) Education, Environmental Education, Social Studies Education, and Related Literacies;
3. Connecting Environmental Literacy and Social-Ecological Resilience;
4. Active Learning, Social Learning, and Co-Production of Knowledge;
5. Equitable Resilience and Climate Justice; and
6. Empowering Agents of Change.

Although there is overlap in the concepts discussed in these clusters, they are grouped because the ideas discussed in each of these sections are most closely related. This literature, as well as lessons learned from the ELP Community of Practice, are the basis for the set of assumptions that explain the relationship within and among the causal pathways of the ELP theory of change.

Resilience to Extreme Weather, Climate Change, and Other Environmental Hazards

Extreme weather, climate change, and other environmental hazards pose serious and increasing threats to human health and safety, the economy, and the environment, particularly under a future with high greenhouse gas emissions. Climate change is projected to increase the frequency and intensity of some extreme weather events (USGCRP 2018). Billion-dollar weather and climate disasters are becoming more frequent and costly in the United States. Specifically, the United States has sustained 265 weather and climate disasters since 1980, where the cost of damages either reached or exceeded $1 billion, with the total cost of these damages reaching a soaring $1.775 trillion. Additionally, despite improvements in forecasting and warning systems, there has also been a rise in the number of deaths associated with these billion dollar events (NCEI 2020). Globally averaged surface air temperatures are now the warmest in the history of modern civilization, with greenhouse gas emissions from human activities being the most significant contributors to the observed warming (USGCRP 2018). As such, emission mitigation and adaptation actions play a direct role in determining future risks and climate impacts.

The environmental hazards that are most relevant to the ELP's work are those that are part of NOAA's mission which include, but are not limited to, severe storms, tornadoes, hurricanes, flooding, heavy precipitation events, persistent drought, heat waves, wildfires, increased global temperatures, acidification of the ocean, and sea level rise. It is important to note the differing temporal component of these hazards. Some of them are acute, short-term events such as severe storms and wildfires, whereas others are chronic stressors such as increasing global temperatures, ocean acidification, and sea level rise that play out over a longer period of time. As a result, different actions are needed to address these different types of hazards. Furthermore, these hazards are interrelated and have compounding impacts, placing some groups at higher risk of climate-related impacts than others (USGCRP 2018).

Many factors contribute to individual and community exposure and capacity to respond to extreme weather, climate change, and other environmental hazards, which range from social, economic, to geographic variables. Risks are often higher for low-income communities, communities of color, other historically marginalized groups, children, and the elderly. Climate change is projected to exacerbate existing socioeconomic inequalities, which can in turn heighten exposure to environmental hazards and other climate-related impacts (USGCRP 2018).

A key strategy to reduce vulnerability to extreme weather, climate change, and other environmental hazards is to bolster community resilience. Community resilience is dependent upon the strength of all aspects of a community, including educational attainment, physical infrastructure, socioeconomic health, social networks, and ecosystem health. Communication across social networks and education are key components of community resilience, where resilience is increased when community members develop an understanding of the current and projected environmental hazards they face, and the actions they can take to both plan for and respond to an event (NRC 2012). The National Research Council highlights that while education and communication about resilience should take place at all scales of governance, these approaches "may be most crucial at the local level, where they strengthen social ties and capabilities, and where local knowledge and trusted relationships can amplify the power of communications" (2012, 134).

Public health is another facet of community resilience. In addition to extreme weather, climate change, and other environmental hazards, pandemics pose serious challenges to communities, and a community's response to a pandemic might share similarities to its response to an extreme weather event. A Presidential Policy Directive (PPD-8) from 2011 entitled "National Preparedness" describes how catastrophic weather events, pandemics, terrorism, and cyberattacks all pose threats to national security (White House and Department of Homeland Security 2011). This policy directive highlights commonalities in responses to these threats. For

example, leveraging expertise and knowledge at the community level would be required for both a pandemic and an environmental disaster like a large-scale oil spill. Furthermore, as the COVID-19 pandemic has brought to light, community preparedness to respond to the pandemic has varied across the nation, and health disparities exist wherein low-income communities and communities of color are disproportionately impacted by the virus. Opportunities exist for increasing both communication across social networks and education to better prepare communities for these challenges.

Science, Technology, Engineering, and Math (STEM) Education, Environmental Education, Social Studies Education, and Related Literacies

The definition put forward for community resilience education encompasses a multi-disciplinary effort that involves STEM, environmental, and social studies educational approaches and draws from concepts contained in the definitions of scientific literacy, geographic literacy, climate literacy, and environmental literacy. Environmental literacy is the singular literacy called out in the community resilience education definition and in the program's goals and approaches because it integrates many of the elements of the other literacies.

Environmental Literacy

NOAA has adopted the following definition of environmental literacy: the possession of knowledge and understanding of a wide range of environmental concepts, problems, and issues; cognitive and affective dispositions toward the environment; cognitive skills and abilities; and appropriate behavioral strategies to make sound and effective decisions regarding the environment. It includes informed decision making both individually and collectively and a willingness to act on those decisions in personal and civic life to improve the well-being of other individuals, societies and the global environment (NOAA 2015-2035 Education Strategic Plan). This was adapted from the definition used by the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) (Hollweg et al. 2011, 2-3). A primary goal of environmental education (EE) is to develop environmental literacy, with the objective of fostering responsible citizens and stewards of the planet (Roth 1992).

Scientific Literacy

Scientific literacy, as put forward by the OECD PISA is:

> [T]he ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies of:
>
> - Explaining phenomena scientifically - Recognising, offering and evaluating explanations for a range of natural and technological phenomena.
> - Evaluating and designing scientific enquiry - Describing and appraising scientific investigations and proposing ways of addressing questions scientifically.
> - Interpreting data and evidence scientifically - Analysing and evaluating data, claims and arguments in a variety of representations and drawing appropriate scientific conclusions (OECD 2018).

ELP-funded projects are rooted in STEM Education efforts that build scientific literacy in their target audiences, among other educational goals.

Geographic Literacy

Geo-literacy or geographic literacy, put forward by the National Geographic Society, is defined as “the understanding of human and natural systems, geographic reasoning, and systematic decision-making”, where ”geographic reasoning is the process of making informed, logical decisions based on accurate understanding of the human and natural world around you” (2020). Understanding and taking action to address environmental hazards requires an ability to comprehend spatial data, and is an inherently place-based effort. Therefore, geographic literacy, fostered through social studies education, among other approaches, underpins the ELP’s work in community resilience education.

Climate Literacy

NOAA and a large group of other federal agencies reached consensus on the essential components of understanding climate science, and put forth the definition of climate science literacy as:

- Understanding the essential principles of Earth’s climate system;
- knowing how to assess scientifically credible information about climate;
- communicating about climate and climate change in a meaningful way; and
- being able to make informed and responsible decisions with regard to actions that may affect climate (USGCRP 2009).

ELP-funded projects are designed to help build the multiple domains of climate literacy as outlined in the Essential Principles of Climate Science (USGCRP 2009).

The complexity of addressing the challenges associated with extreme weather, climate change, and other environmental hazards highlights the need for society to have some level of competency within each of these literacies. Building sufficient levels of environmental literacy among community members ensures that they comprehend the complex ways that human and natural systems interact, both globally and locally, and have the required skills, motivation, and confidence to participate in decisions that inform public policy. Decisions about how to build more resilient and equitable communities should be based on scientific and other forms of knowledge (e.g., traditional and community knowledge), and represent the values of society. Such decisions can lead to more robust policies that will be better accepted by society because they truly reflect that society's values (Bozeman and Sarewitz 2011). STEM education, environmental education, and social studies education all contribute to building the needed competencies. These types of holistic and multi-disciplinary approaches are foundational for community resilience education.

Environmental Literacy Exists on a Continuum

While society at large has a tendency to understand literacy as binary—either present or not—all types of literacy exist on a continuum. Environmental literacy changes over time within individuals as a person's beliefs, life experiences, and social influences modify their understanding of and response to environmental issues (Hollweg et al. 2011, 3-11). Additionally, environmental literacy within an individual can exist at different levels of proficiency. Environmental literacy is a complex combination of knowledge, dispositions, skills and behavior that interact and influence each other (Figure 2) (Hollweg et al. 2011). Environmentally responsible behavior is the goal of environmental literacy and it results from possessing degrees of the other three components. Knowledge of an environmental issue is a key component, as are concerns about a given issue and one's willingness to take action. Understanding and caring about an environmental issue are insufficient on their own; one also must possess the skills to apply the knowledge and act on that motivation. These three components are necessary for environmentally responsible behavior and that behavior can, in return, build knowledge and skills in the process of taking action (i.e., learning by doing). It is also important to note that an individual's environmentally responsible behavior is mediated through personal, social, and physical contexts (Hollweg et al. 2011, 3-11 to 3-12).

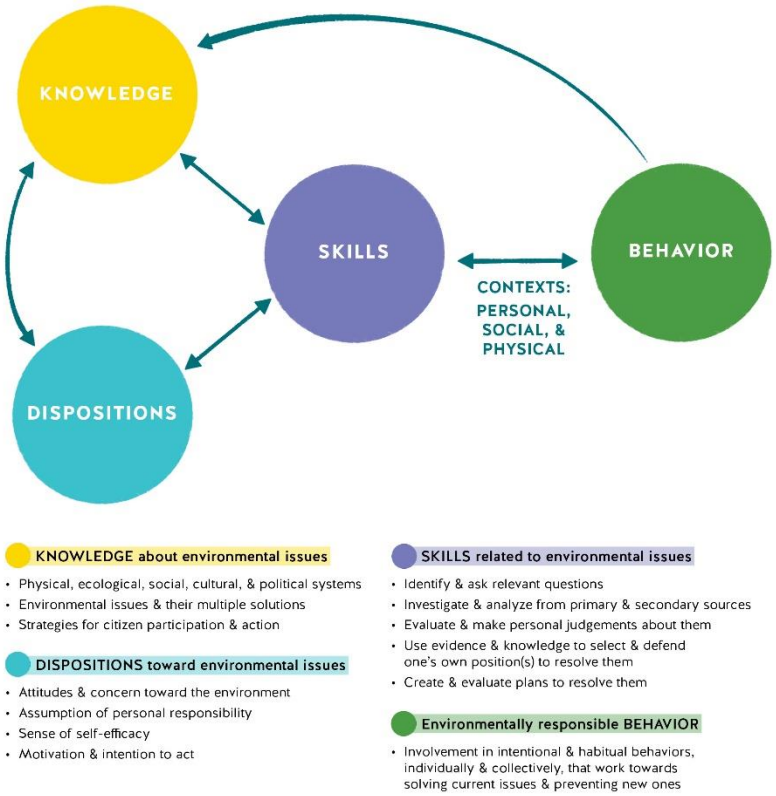

Figure 2. Components of environmental literacy and their relationship to one another, adapted from Hollweg et al. (2011).

Assessing levels of environmental literacy involves analyzing the degree to which individuals attain proficiency within each component, and are able to apply their knowledge and skills to decision making on local, regional, national, and global environmental issues (Hollweg et al. 2011, ii). Levels of environmental literacy have been described as three points on a continuum, including nominal, functional, and operational literacy (Roth 1992, 17).

> ***Nominal environmental literacy*** indicates a person able to recognize many of the basic terms used in communicating about the environment and able to provide rough, if unsophisticated, working definitions of their meanings. Persons at the nominal level are developing an awareness and sensitivity towards the environment along with an attitude of respect for natural systems and concern for the nature and magnitude of human impacts on them. They also have a very rudimentary knowledge of how natural systems work and how human social systems interact with them.

> ***Functional environmental literacy*** indicates a person with a broader knowledge and understanding of the nature of and interactions between human social systems and other natural systems. They are aware and concerned about the negative interactions between these systems in terms of at least one or more issues and have developed the skills to analyze, synthesize, and evaluate information about them using primary and secondary sources. They evaluate a selected problem/issue on the basis of sound evidence and personal values and ethics. They communicate their findings and feelings to others. On issues of particular concern to them, they evidence a personal investment and motivation to work toward remediation using their knowledge of basic strategies for initiating and implementing social or technological change.
>
> ***Operational environmental literacy*** indicates a person who has moved beyond functional literacy in both the breadth and depth of understandings and skills who routinely evaluate the impacts and consequences of actions; gathering and synthesizing pertinent information, choosing among alternatives, and advocating action positions and taking actions that work to sustain or enhance a healthy environment. Such people demonstrate a strong, ongoing sense of investment in and responsibility for preventing or remediating environmental degradation both personally and collectively, and are likely to be acting at several levels from local to global in so doing. The characteristic habits of mind of the environmentally literate are well ingrained. They are routinely engaged in dealing with the world at large (26).

Collective Literacy

Just as environmental literacy can be understood to exist on a continuum within an individual, there is also a continuum of literacy held within a community. This community-level literacy can be referred to as collective literacy. For instance, the National Academies Committee on Science Literacy and Public Perception of Science asserts that

> Science literacy in a community does not require each individual to attain a particular threshold of knowledge, skills, and abilities; rather, it is a matter of a community having sufficient shared resources that are distributed and organized in such a way that the varying abilities of community members work in concert to contribute to the community's overall well-being (2016, 73).

This community literacy concept has evolved and was further articulated in the 2018 National Academies report *Learning through Citizen Science: Enhancing Opportunities by Design*, where

> Community science literacy is the capacity of a community to apply, do, and even guide science in ways that advance community priorities. It is a shared capacity, and it

> depends on and relates to the science learning of individuals as well as the connections, networks and agency that are distributed throughout the community (2018, 4).

Moreover, efforts to advance science literacy to address complex global issues, including climate change, have largely been unsuccessful, as they've been focused on individual behavior change rather than changes at the societal level (Spitzer and Fraser 2020). This concept of a continuum of literacy within a community can be applied to environmental literacy as well as science literacy. The ELP recognizes that for community resilience education projects to succeed, it is important that they aim to build collective literacy rather than equip all members of a community with the same level of literacy.

Connecting Environmental Literacy and Social-Ecological Resilience

Studies highlight that educated communities are less vulnerable to environmental hazards, as they are more likely to be prepared for and recover from disasters (Frankenberg et al. 2013; Muttarak and Lutz 2014; Sharpe et al. 2018). EE has maintained a focus on fostering environmentally-sensitive behavior and decision making through the cultivation of environmental literacy. Though EE has evolved to adapt to changes in social and ecological systems over time, with the most recent adaptations incorporating principles of environmental justice, youth development, and democratic participation (Dubois and Krasny 2016, 255), the discipline must continue to adapt to address the unprecedented challenges posed by a changing climate.

Many scholars and practitioners have been exploring ways in which environmental literacy and resilience overlap. The concept of social-ecological systems (SES) resilience is particularly useful in helping us understand how larger communities and systems react and transform in response to disturbance. SES resilience can be defined as "the capacity of a social-ecological system to continually change, adapt, or transform so as to maintain ongoing processes in response to gradual and small-scale change, or transform in the face of devastating change" (Folke, Colding, and Berkes 2001). Adaptive capacity, or the "ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change" (U.S. Climate Resilience Toolkit 2020), is a particularly important indicator of a social-ecological system's resilience.

Dubois and Krasny highlight that EE can help foster attributes of resilient human-nature systems, namely social capital, adaptive capacity, and collaborative resource management (2016, 257). Furthermore, concepts from learning theory and SES resilience can be coupled to address complex environmental problems. For instance, research highlights that unexpected events can foster transformational learning–meaning a change in an individual or group's perspective–which can potentially lead to changes in behavior (Dubois and Krasny 2017; Sharpe

et al. 2018). This idea is parallel to SES resilience theory that suggests that disturbances (e.g., an extreme weather event) create opportunities for transformative approaches to environmental management. Therefore, the similarities between learning theory and SES resilience theory further instill the relevance of EE and environmental literacy in building community resilience in social-ecological systems. Projects funded by ELP offer participants exposure to transformative EE approaches, where projects combine concepts of resilience to climate change with concrete steps for taking action to reduce vulnerability in the communities where they are implemented.

Active Learning, Social Learning, and Co-Production of Knowledge

ELP projects employ active and social learning strategies to engage participants in learning about concepts of community resilience and facilitate opportunities for community-based civic engagement. Active learning refers to a broad range of teaching strategies in which learners interactively participate in the learning process, rather than passively receive instruction. It is a process whereby learners engage in activities, such as reading, writing, discussion, or problem solving that promote analysis, synthesis, and evaluation of information. Cooperative learning, problem-based learning, and the use of case methods and simulations are some approaches that promote active learning (Center for Research on Learning and Teaching 2020). Active learning approaches commonly employed by ELP projects include deliberative forums, citizen science, participatory decision making and mapping exercises, and scenario-based or role-playing activities and games. Social learning is learning that goes beyond the individual to be embedded in social networks (Reed et al. 2010). Active and social learning often go hand in hand.

Deliberative Forums

Deliberative forums serve as opportunities for public participation in democratic decision making, and have proven to be an effective active learning approach in ELP-funded projects. They are highly effective for addressing specific types of challenges such as addressing scientific issues of societal relevance. Deliberative forums are structured events that include focused discussion questions, allowing for participants to respond to and share information relevant to the issue at hand, and discuss trade-offs associated with potential solutions. In the context of the ELP, these community forums have been facilitated in collaboration with local resilience practitioners and policy makers, focusing on specific climate threats and potential solutions to address them. These forums promote participatory decision making and offer an alternative to ineffective top-down approaches to public policy generation. By encouraging diverse community members to share their perspectives and participate in the generation of solutions, scientific research and public policies can better reflect community needs and desires (Bach et

al. 2010; Bozeman and Sarewitz 2011). Additionally, community members benefit from participation in deliberative forums by developing literacy of scientific uncertainty, global and place-based environmental phenomena, and potential resilience strategies to reduce local vulnerability to climate impacts (White et al. 2001).

Citizen Science

Another key active learning approach used by multiple ELP-funded projects is citizen science. The Crowdsourcing and Citizen Science Act describes citizen science as

> A form of open collaboration in which individuals or organizations participate voluntarily in the scientific process in various ways, including:
> (A) enabling the formulation of research questions;
> (B) creating and refining project design;
> (C) conducting scientific experiments;
> (D) collecting and analyzing data;
> (E) interpreting the results of data;
> (F) developing technologies and applications;
> (G) making discoveries; and
> (H) solving problems (Crowdsourcing and Citizen Science Act 2017).

The National Academies of Sciences, Engineering, and Medicine define citizen science projects as "those that typically involve nonscientists (i.e., people who are not professionally trained in project-relevant disciplines) in the processes, methods, and standards of research, with the intended goal of advancing scientific knowledge or application" (2018, 13). Other terms may be used to describe citizen science, including community science, volunteer monitoring, public participation in scientific research, community-engaged research, participatory action research, and community-based participatory research. The National Academies recognize the use of the term "citizen" as having negative connotations, or invoking contentious debates about citizenship status and who has a right to participate in civic life. However, citizen science is the most widely used and understood term, and is used here to encompass the concepts of the rest.

A report produced by the Center for the Advancement of Informal Science Education's Public Participation in Science Inquiry Group categorizes public participation in citizen science into three main groupings:

> (1) Contributory projects, which are generally designed by scientists and for which members of the public primarily contribute data;

(2) Collaborative projects, which are generally designed by scientists and for which members of the public contribute data but also may help to refine project design, analyze data, or disseminate findings;

(3) Co-created projects, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process (Bonney et al. 2009, 11).

The more collaborative forms of citizen science can be especially well-suited to advance goals of justice, equity, diversity, and inclusion in projects. These approaches facilitate interactions between scientists and nonscientists, therefore creating opportunities for sharing diverse ideas and helping equip nonscientists with the knowledge, skills, and abilities to apply the scientific process. In particular, citizen science has the potential to engage and empower historically marginalized communities to participate in scientific research, thereby democratizing the research process (English, Richardson, and Garzón-Galvis 2018, 336). Crucially, opportunities to integrate diverse beliefs, epistemologies, and ideas that have been previously excluded from science "will only be realized if diversity, equity, and inclusion are part of the goals in the design and implementation of citizen science" (NASEM 2018, 18). Citizen science can contribute to increased community science literacy (Hoffman 2020), and can increase transparency and accountability in the scientific process, from developing research questions to data collection and analysis (NASEM 2018). Overall, public participation in science research creates opportunities for more equitable engagement with science, makes research more relevant to participant's daily lives and their communities, and elevates the value of science in society.

Social Learning and Co-Production of Knowledge

Knowledge co-production has grown in popularity as a useful approach to addressing complex challenges of sustainability, climate change adaptation, and resilience planning. Armitage et al. defines co-production of knowledge as "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" (2011, 996). Like citizen science, knowledge co-production is recognized as part of a group of emerging participatory and transdisciplinary approaches. These approaches promote equitable interactions between academics and non-academics, practitioners and community members to produce knowledge and solutions to context-specific challenges, rejecting the notion that only scientists have a role to play in conducting research to address social-ecological issues (Norström et al. 2020).

Adaptation to climate change is understood as a process that involves evaluating and negotiating trade-offs, considering the consequences of different options, and information sharing among diverse groups. As such, learning is an essential component of adaptation, with social learning in particular being increasingly identified as a key approach to effective adaptation (Armitage et al. 2011). The concept of social learning has evolved over time from referring to individual learning in social contexts, to learning in collective units, and has been applied to many sectors including environmental education, climate change adaptation, ecological sustainability, and resilience narratives and practice (Sharpe et al. 2018).

Social learning supports the co-production of knowledge, and can be facilitated through opportunities to share knowledge, values, and actions to respond to climate change and extreme weather events. Learning amongst peers, rather than through one-way instruction, can lead to faster and deeper forms of knowledge acquisition and skill-building (Sharpe et al. 2018). Social learning is closely linked to transformational learning, in that it encourages critical reflection that can help stakeholders acknowledge established ways of thinking that may be detrimental, particularly in the context of community resilience and disaster response. This critical reflection can take place at an individual and community scale, and is essential to initiate behavior change toward increasing resilience to climate change (Sharpe et al. 2018).

Moreover, social learning practices allow for community and place-based modes of knowledge generation that evolve over time and are adaptable to the specific needs and desires of a particular community. Place-based, adaptable approaches create opportunities for integration of diverse community values that can lead to transformative changes in public policies and environmental governance. The active learning approaches employed by ELP projects—such as citizen science, deliberative forums, participatory decision making and mapping exercises, and scenario-based or role-playing activities and games—create venues for social learning to take place. Though these approaches differ from one another, they share commonalities in that they bring people together to consider complex scenarios and to work collectively toward a shared goal.

Each of these active learning approaches require strong facilitation, allowing diverse perspectives to be shared and negotiated. In addition, social learning places strong emphasis on communication, which helps participants cultivate confidence to take part in generating solutions and build trust with one another. If the active learning approach includes involvement with local officials, resilience practitioners, and decision makers, these activities can lead to the creation of public policies that reflect more democratic participation. This is significant, as research analyzing the role that community values play in science policy demonstrates that

policies are more robust and socially accepted if they reflect a society's public values[5] (Bozeman and Sarewitz 2011).

It is important to note that social learning at a community level may not always be easy, as it is sometimes difficult to generate solutions when community members hold opposing views. However, creating opportunities for collaborative approaches to addressing shared issues is a sustainable path forward, and diverse perspectives in active social networks can lead to increased community resilience (Sharpe et al. 2018).

The social networks necessary for these collaborative approaches are considered a facet of social capital. The National Academies of Sciences, Engineering, and Mathematics define social capital as:

> The social networks and connectivity among groups and individuals within a community. [Social capital] includes levels of trust and reciprocity, political engagement, length of residence, volunteerism, religious affiliation, and community organizations and services. Also included is the feeling of belonging to and a sense of place about the community (2019, 14).

While efforts to measure social capital are challenging, experts assert that social capital, along with natural, built, financial, human, and political "capitals", are essential for achieving community resilience (NASEM 2019). Social capital is built in the communities in which ELP projects are implemented through the many social and active learning opportunities created by ELP grantees.

Related to social capital is the concept of social cohesion, or the "extent to which groups and communities cooperate, communicate to foster understanding, participate in activities and organizations, and collaborate to respond to challenges (e.g., a natural disaster or disease outbreak)" (National Research Council 2014, 34). Social cohesion represents the conditions that facilitate civic engagement. Civic engagement can take many forms, and can be understood as the efforts and activities one undertakes to influence civic life through both political and non-political processes (Ehrlich 2000). When social cohesion is present, community engagement in resilience building efforts helps to facilitate buy-in around local priorities and goals related to resilience planning and practices (NASEM 2019). In summary, social learning contributes to building social capital, which bolsters social cohesion and community engagement, which in turn strengthens community resilience.

[5] "A society's 'public values' are those providing normative consensus about (1) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (2) the obligations of citizens to society, the state and one another; (3) and the principles on which governments and policies should be based" (Bozeman 2007, 37).

Equitable Resilience and Climate Justice

Environmental and climate justice scholars, advocates, and practitioners have been instrumental in articulating how low-income communities, communities of color, indigenous and tribal communities, and immigrant communities have long been disproportionately impacted by environmental hazards in the United States (Pulido 2000; Cole and Foster 2001; Morello-Frosch et al. 2002; Brulle and Pellow 2006; Morello-Frosch et al. 2011; Cushing et al. 2015). Climate change exacerbates the existing challenges and injustices faced by these communities (Pettit 2004; Harlan et al. 2015; USGCRP 2018). To build equitable community resilience to extreme weather, climate change, and other environmental hazards, the needs of historically marginalized communities must be addressed. Democratic and inclusive decision-making processes allow for previously marginalized voices to be heard and elevated. Furthermore, climate adaptation and environmental policies should take into account the uneven distribution of risks and cumulative impacts borne by marginalized groups in order to create lasting change (Morello-Frosch et al. 2011; Bulkeley et al. 2013).

Several ELP-funded projects have demonstrated success in engaging historically marginalized communities through partnering with community-based organizations. Community-based organizations are defined as:

> Organizations that are driven by community residents in all aspects of their existence. This means that: the majority of the governing body and staff consists of local residents; the main operating offices are in the community; the priority issue areas are identified and defined by residents; solutions to address priority issues are developed with residents; and program design, implementation, and evaluation components have residents intimately involved in leadership positions (National Community–Based Organization Network 2011).

By partnering with these trusted community groups, ELP project teams are able to reach members of their communities whom they had not been able to previously. Project goals of building community resilience to climate change are most likely to be achieved when they are aligned with ongoing community development efforts.

So what does equitable resilience to climate change look like? Matin, Forrester, and Ensor (2018) assert that equitable resilience "is increasingly likely when resilience practice takes into account issues of social vulnerability and differential access to power, knowledge, and resources; it requires starting from people's own perception of their position within their human-environmental system, and it accounts for their realities and for their need for a change of circumstance to avoid imbalances of power into the future" (197). The Greenlining Institute's 2019 report *Making Equity Real in Climate Adaptation and Community Resilience Policies and*

Programs provides actionable recommendations for how to integrate social equity into the goals and implementation of policies and grant programs that aim to build community resilience to climate change. These recommendations include embedding equity into program mission, vision, and values; building equity into the process; ensuring equitable outcomes; and measuring and analyzing for equity (The Greenlining Institute 2019). Only when existing inequities and imbalances of power are addressed will communities truly be resilient. ELP will continue to prioritize equitable approaches to building community resilience to extreme weather, climate change, and other environmental hazards.

Empowering Agents of Change

In recent decades, efforts to educate about climate change have failed to inspire children, youth, and adults to take sufficient action. While there are many reasons for this inaction unrelated to education, most educational approaches to date have had limited effectiveness in inspiring change because they have been too focused on the causes, the global scale of the problem, and impacts too distant from the learners (Flora et al. 2014; Leiserowitz et al. 2019). These challenges highlight the need to improve the public understanding of how climate change can manifest at the community level, and to help community members contextualize how individuals and the places they love could be impacted (Moser and Pike 2015). To complicate matters further, as learners acquire more knowledge about climate change and its impacts, they are often stifled by feelings of hopelessness and anxiety caused by comprehending the magnitude of the impacts and the complexity of the problem (Doherty and Clayton 2011; Ojala 2012; Clayton, Manning, and Hodge 2014).

Emphasizing Solutions and Place-based Relevance

To address these challenges, researchers and climate education experts find that hope serves as a "precondition to action" (Niepold, Poppleton, and Kretser 2018, 17). "Stubborn optimism" and an ability to envision a better future motivate people to take action (Figueres and Rivett-Carnac 2020). Rather than focusing on the causes of climate change, research suggests that climate change communication is more effective and likely to lead individuals to take action if the emphasis is on solutions (Moser and Dilling 2007; Moser 2014). Further, if these solutions address local impacts and emphasize co-benefits of action, educators and climate change communicators are better able to demonstrate the relevance of the issue to their audiences (Moser and Dilling 2007).

Additional research highlights the potential for place-based understandings of climate change to overcome political polarization on the issue, and to help motivate individuals to participate

in climate adaptation planning processes (Adger et al. 2013). Significantly, “it is in specific locales where people must live with the consequences of adaptation choices and where people’s sense of place can be a motivation or hindrance to action” (Moser and Pike 2015, 112).

Inspiring Youth Engagement

Climate change and its impacts are at the forefront of issues threatening youth. There is an ongoing need to support youth in taking action to make their communities more resilient to climate impacts, specifically by improving their confidence in making climate-smart decisions and taking civic action (Flora et al. 2014). As noted previously, the ELP’s shift in focus from climate change education to community resilience education was done to encourage projects to create place-based solutions to address the specific vulnerabilities facing the communities they reach. This new emphasis on solutions empowers project participants, in particular, youth, to take action at the individual, school, and community level.

By equipping youth with the knowledge, skills, and confidence necessary for communicating climate change and its impacts, ELP projects help youth see themselves–and be seen–as leaders in their communities. Confidence and a sense of leadership can help youth recognize their own self-efficacy and agency to make a difference (Clayton, Manning, and Hodge 2014; Kretser and Chandler 2020). Also, it is critical that youth develop the skills to navigate through complex decisions they face now and will face in the future. ELP-funded projects engage youth and empower them to be agents of change within their communities. Funded projects use many approaches to engage youth ranging from youth summits, to student-driven action projects, to facilitating opportunities for youth to interact and partner with stakeholders, local officials, and other resilience practitioners in their communities. Youth can be enthusiastic and imaginative, and when seen as partners in community resilience planning, their potential to influence their families, peers, and communities to make climate-smart decisions may be realized.

Conclusion

As noted in the introduction to this section, many of the concepts explored in this literature review intersect and reinforce each other (e.g., social cohesion and equitable and inclusive community engagement, social learning and collective literacy). All the concepts explored above contribute to community resilience in some way and therefore informed the development of the ELP Community Resilience Education Theory of Change.

Section III: Navigating the NOAA ELP Community Resilience Education Theory of Change

A theory of change begins with a problem statement and ends with a goal. In between, causal pathways depict the short-, mid-, and long-term outcomes that must be met in order to achieve the end goal. Theories of change typically include an end goal that is idealistic and far-reaching. The end goal here is large in scope and it cannot be accomplished by NOAA or ELP alone. Therefore, an intermediate goal that articulates how ELP contributes to the end goal has also been written and is referred to as the ELP goal. Interventions provided by the agency and program show how both are working to address the challenges laid out in the problem statement to achieve the end goal.

Based on the approaches and outcomes from the ELP-funded community resilience education projects and assumptions gleaned from the literature review discussed in Section II, six causal pathways have been identified so far. Each pathway reflects outcomes from multiple projects and the pathways are not meant to be prescriptive. Successful projects may achieve outcomes in several different causal pathways and not all projects will achieve all of the long-term goals in a pathway. Most of the short- and mid-term outcomes encompassed in these pathways are already occurring in existing projects, whereas the long-term outcomes are aspirational and may occur with more effort (i.e., more than one project) and over a longer time period. Community resilience education projects can be evaluated based on pathway outcomes, although impact evaluation would likely include outcomes specific to project goals and context.

These short-, mid-, long-term, and program outcomes are the necessary preconditions for achieving the goals that have been articulated. In some cases there is a hierarchy within the short- or mid-term groups of outcomes. The arrangement of the outcomes (from top to bottom) indicates some level of sequence although not necessarily a dependence (that one outcome must occur before the next outcome occurs). If there is a strong dependence of one outcome on another, that is noted in a footnote.

These six causal pathways are not the only means to achieve community resilience through education. As the program evolves, additional outcomes and/or causal pathways may be developed. Beyond those funded through NOAA's ELP, other institutions may identify other outcomes or causal pathways that contribute to the end goal articulated in this theory of change. This additional perspective and input will be welcome. For this reason, this theory of change will remain a living document that will be updated regularly to reflect progress made by the ELP, as well as contributions from others in the field of community resilience education.

Finally, to provide a synopsis of the major outcomes from all six causal pathways and relate these to the problem statement, interventions, and ELP and end goals, a “Pathway to Change” has been created and serves as the abstract of the entire theory of change.

Section IV: The ELP Community Resilience Education Theory of Change

The remainder of this report presents the 2020 version of NOAA's ELP Community Resilience Education Theory of Change:

- Problem Statement
- NOAA's Interventions
- ELP's Interventions
- Causal Pathways[6]
    - ELP Project Interventions
    - Short-, Mid-, and Long-term Outcomes
    - ELP Outcome
- ELP Goal
- End Goal

An illustration of the ELP Vision of a Resilient Community representing the end goal (Figure 3) is included below. In total, more than 100 outcomes were identified across the six causal pathways and the Pathway to Change.

Problem Statement

Communities in the United States are facing challenges of not only recovering from on-going extreme weather events and other environmental hazards, but also preparing for a future of more frequent and damaging events caused by climate change (Lempert et al. 2018; NCEI 2020; Weather-ready Nation: NOAA's National Weather Service Strategic Plan 2019-2022). Climate change threatens human health and safety, ecosystem health, and social and economic well-being (USGCRP 2018). The geographic distribution of climate change impacts is uneven, and long-standing socio-economic inequities heighten vulnerabilities for underserved groups. These threats become even greater with the increasing rates of greenhouse gas emissions (USGCRP 2018). The severity of future climate impacts will depend largely on national-scale and community-level actions taken to reduce greenhouse gas emissions and to adapt to the changes that will continue to occur.

[6] The components that are consistent across all causal pathways include: the problem statement, NOAA's interventions, the ELP's interventions, the intermediate goal (i.e., the ELP goal), and the end goal. What is unique in each causal pathway are the ELP-funded project interventions, short-, mid-, and long-term outcomes, and the ELP outcome.

To prepare for a future of increasing environmental hazards, communities need to implement more policies and practices that allow their members, regardless of socioeconomic status, to thrive and be resilient. These policies and practices should be informed by engaged community members and leaders who understand the causes of climate change and its impacts on their own lives now and in the future. Decisions about how to build more resilient and equitable communities should be based on scientific and other forms of knowledge (e.g., traditional and community knowledge), and represent the values of society. Such decisions can lead to more robust policies that will be better accepted if they truly reflect that society's values (Bozeman and Sarewitz 2011). Increasing environmental literacy among community members ensures that they comprehend the complex ways that human and natural systems interact, both globally and locally, and have the required skills, motivation, and confidence to participate in decisions that inform public policy.

Education is the primary means for building environmental literacy. Nevertheless, despite decades of efforts to educate about climate change, many community members do not prioritize climate change mitigation and adaptation solutions, and this is evident in the lack of political will and civic engagement on the issue (Leiserowitz 2019). While there are many reasons for this inaction that are not related to education, many educational approaches to date have been ineffective to inspire change because they have been too focused on the causes, the global scale of the problem, and impacts too distant from the learners (Flora et al. 2014; Leiserowitz et al. 2019). Further, as learners acquire more knowledge about climate change, they are often stifled by feelings of hopelessness and anxiety caused by comprehending the magnitude of the impacts and the complexity of the problem (Doherty and Clayton 2011; Ojala 2012; Clayton, Manning, and Hodge 2014). Together, these challenges call for different approaches to educating for community resilience to extreme weather, climate change, and other environmental hazards.

NOAA's Interventions

NOAA focuses on four long-term goals that make important contributions to resilient ecosystems, communities, and economies. These goals include: Climate Adaptation and Mitigation, Weather-ready Nation, Healthy Oceans, and Resilient Coastal Communities and Economies.

ELP's Interventions

In response to the great need throughout the United States, NOAA's Environmental Literacy Program (ELP) supports the development and strengthening of resilient communities through

competitive grants, in-kind support (including NOAA personnel and other scientific assets) and an ELP Community of Practice.

List of Causal Pathways

Six causal pathways that describe the project-level interventions; the short-, mid-, and long-term outcomes; and the ELP-level outcome achieved through each pathway are included in this section.

- Causal Pathway 1: ELP Community of Practice Advances Effective Approaches
- Causal Pathway 2: Resilience Planning and Policies Integrate Education
- Causal Pathway 3: Active Learning enables Community Engagement in Civic Processes
- Causal Pathway 4: Understanding Cultural and Historical Context of Place Builds Social Cohesion
- Causal Pathway 5: Student-driven Action Projects Implement Resilience Measures
- Causal Pathway 6: Youth Summits Empower Agents of Change

ELP Goal

Communities have sufficient collective environmental literacy to take actions that build resilience to extreme weather, climate change, and other environmental hazards in ways that contribute to community health, social cohesion, and socio-economic equity. These communities are composed of individuals who participate in formal and informal education experiences that develop their knowledge, skills, and confidence to:

- reason about the ways that human and natural systems interact globally and locally, including the acknowledgement of disproportionately distributed vulnerabilities;
- participate in civic processes; and
- incorporate scientific information, cultural knowledge, and diverse community values in decision making.

End Goal

Communities are resilient to current and future environmental hazards in that they have the capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment. Environmental literacy—along with community health, civic engagement, social cohesion, and equity—enhance resilience. Stewardship of healthy ecosystems, a low-carbon economy, and climate-smart and inclusive decision-making further reduce risks from current and future environmental hazards.

Figure 3. This illustration of the ELP Vision of a Resilient Community depicts several key aspects of the ELP Community Resilience Education Theory of Change. The ELP and end goals are brought to life through this portrayal of the future. The illustration also depicts all of the major institutional players, such as museums, aquariums, K-12 schools, universities and other educational and community-based organizations; the audiences; and the key approaches that have been identified as effective in using education to build community resilience. Children, youth, and adults are learning together and are directly engaged in activities that improve the resilience of their community.

Pathway to Change

PROBLEM STATEMENT[7]

- Climate change is an increasing threat and communities are not fully prepared;
- Some groups are more vulnerable than others;
- More policies and actions that promote preparation, adaptation, and greenhouse gas mitigation are needed; and
- Policies and actions need to be informed by, and reflect the values of, community members.

[7] This version of the problem statement is an abstract of the full-text version provided in Section IV.

Therefore…

- Communities need the collective skills, knowledge, and confidence (i.e., environmental literacy) to participate in decision making that informs policies and practices; and
- Different education approaches are needed to build environmental literacy and encourage civic engagement around resilience.

NOAA's INTERVENTIONS

NOAA focuses on four long-term goals that make important contributions to resilient ecosystems, communities, and economies. These goals include: Climate Adaptation and Mitigation, Weather-Ready Nation, Healthy Oceans, Resilient Coastal Communities and Economies.

ELP's INTERVENTIONS

In response to the great need throughout the United States, NOAA's Environmental Literacy Program (ELP) supports the development and strengthening of resilient communities through competitive grants, in-kind support (including NOAA personnel and other scientific assets), and an ELP Community of Practice.

SHORT-TERM OUTCOMES

- Children, youth, and adults learn about the most pertinent environmental hazards of the place where they live and potential solutions.
- Community members develop an understanding of the history, culture, and lived experiences of diverse community members and the socio-economic factors of environmental hazards.
- Civic engagement opportunities for community resilience are explicit and accessible to community members.
- Community members are familiar with local and state resilience plans and can use science tools to make informed decisions.
- Community members have the knowledge, skills, and confidence to implement solutions to improve community resilience[8].
- Community resilience education grantees convene and share their findings.
- Education organizations create new partnerships with local and state government offices charged with resilience efforts.

[8] Within this level of outcomes, the first four outcomes occur before this one does.

MID-TERM OUTCOMES

- Educational activities support local and state government resilience efforts[9].
- Resilience practitioners value and support education projects.
- Youth act as agents of change to increase resilience in their community.
- Student-driven, and educator supported, action projects improve community resilience.
- NOAA's ELP Community of Practice advances effective community resilience education.
- Diverse community members are civically engaged and make informed contributions to resilience decisions[10].
- Community members help practitioners implement equitable and culturally relevant preparedness, adaptation, and carbon mitigation actions.

LONG-TERM OUTCOMES

- Collective environmental literacy is built among children, youth, and adults within a community.
- Equity is central to community resilience education approaches.
- Social cohesion is increased, contributing to community resilience.
- Community resilience policies reflect the values of society.
- Government resilience policies and plans incorporate and provide support for community resilience education.
- Community members feel hopeful and are motivated to take action[11].
- Community members understand and act in support of local and state resilience efforts.
- Communities have greater adaptive capacity.

ELP OUTCOME = ELP GOAL[12]

Communities have sufficient collective environmental literacy to take actions that build resilience to extreme weather, climate change, and other environmental hazards in ways that contribute to community health, social cohesion, and socio-economic equity. These communities are composed of individuals who participate in formal and informal education experiences that develop their knowledge, skills, and confidence to:

- reason about the ways that human and natural systems interact globally and locally, including the acknowledgement of disproportionately distributed vulnerabilities;
- participate in civic processes; and

[9] This outcome is a precondition for the one that comes after it.
[10] This outcome is a precondition for the one that comes after it.
[11] This outcome is a precondition for the one right after it.
[12] The program outcome for the ELP Pathway to Change is the ELP Goal of the Theory of Change.

- incorporate scientific information, cultural knowledge, and diverse community values in decision making.

END GOAL

Communities are resilient to current and future environmental hazards in that they have the capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment. Environmental literacy—along with community health, civic engagement, social cohesion, and equity—enhance resilience. Stewardship of healthy ecosystems, a low-carbon economy, and climate-smart and inclusive decision making further reduce risks from current and future environmental hazards.

CAUSAL PATHWAY 1: ELP COMMUNITY OF PRACTICE ADVANCES EFFECTIVE APPROACHES

ELP PROJECT INTERVENTIONS

ELP-funded projects collaborate as part of NOAA's ELP Community of Practice.

SHORT-TERM OUTCOMES

- Effective approaches for community resilience education emerge and are shared.
- Effective approaches are incorporated into currently funded projects and individual projects improve.
- Collective needs are continually identified and assessed.
- Members collaborate on projects
- Members support each other through ever-increasing strength of social bonds.
- Members of the community of practice increase knowledge and skills related to community resilience education.

MID-TERM OUTCOMES

- Future projects are proposed to ELP funding solicitations that represent an amalgamation of effective approaches from other funded projects or formal collaborations among different grantees.
- Grantees spur additional action in community resilience education by organizing efforts among institutions working in similar areas.
- Grantees organize sessions at conferences that they don't typically attend to increase the awareness of effective approaches and to reach new professional audiences.
- Grantees collaborate to submit articles to peer-reviewed publications that describe effective approaches used across multiple projects.
- Priorities emerge from convenings of the community of practice that are incorporated into ELP's funding solicitations, addressed through learning opportunities, and considered for revisions to this theory of change.
- New funders sustain and scale up ELP-funded effective community resilience educational approaches.
- A collective understanding of effective community resilience education is held among members.

LONG-TERM OUTCOMES

- Educators, not funded by ELP, are influenced by and use approaches identified by the NOAA ELP Community of Practice.
- Resilience practitioners seek the expertise of members of the NOAA ELP Community of Practice.

ELP OUTCOME

NOAA's ELP Community of Practice advances effective community resilience education both in individual projects and collectively through regular collaboration among grantees and sharing of findings within and beyond the community of practice.

CAUSAL PATHWAY 2: RESILIENCE PLANNING AND POLICIES INTEGRATE EDUCATION

ELP PROJECT INTERVENTIONS

ELP-funded projects support local community resilience efforts by incorporating relevant resilience plans and partnering with resilience practitioners.

SHORT-TERM OUTCOMES

- Community resilience education projects incorporate elements of resilience plans.
- Resilience practitioners commit to being an advisor on, and/or participant in, community resilience education projects.

MID-TERM OUTCOMES

- Resilience practitioners collaborate with members of the project team and provide on-going guidance on the implementation of the project.
- Resilience practitioners support education as an essential process for achieving environmental literacy and helping to build community resilience.

LONG-TERM OUTCOMES

- Resilience practitioners recognize and champion collective environmental literacy of children, youth, and adults as being necessary to achieve community resilience.
- With community input, resilience practitioners integrate K-12 and informal education goals and approaches into their community's resilience plan.

ELP OUTCOME

Government policies and budgets provide resources (funding, personnel, etc.) to implement educational components of resilience efforts.

CAUSAL PATHWAY 3: ACTIVE LEARNING ENABLES COMMUNITY ENGAGEMENT IN CIVIC PROCESSES

ELP PROJECT INTERVENTIONS

ELP-funded projects incorporate scientific and policy information into, and provide active learning (e.g., citizen science, deliberative forums, scenario-based interactives, and participatory decision making) opportunities to engage community members in civic processes.

SHORT-TERM OUTCOMES

- Community members are knowledgeable about local resilience plans, interact with local resilience practitioners, and learn how to contribute to resilience planning.
- Community members understand how to prepare better for extreme weather events.
- Community members understand the disparate vulnerabilities existing in their community and the connection between community resilience and health.
- Community-based organizations are engaged to enable members from historically underserved and marginalized groups within the community to have a voice in resilience planning and implementation.
- Museums, aquariums, science centers and other informal education institutions have increased capacity to engage their local community and serve as hubs for resilience.
- Community members participate in data collection and perform investigations that inform resilience planning.
- Community members work together to develop a collective understanding of local environmental hazards by identifying and defining the scope of the problem.
- Community members develop an appreciation for trade-offs and uncertainty inherent in resilience planning.

MID-TERM OUTCOMES

- Museums, aquariums, science centers and other informal education institutions play leadership roles in enabling community-driven resilience.
- Community members feel empowered to improve their community and that their voices are heard in resilience decisions.
- Community members, including those from historically underserved and marginalized communities, have the knowledge, skills, and confidence (i.e., environmental literacy) to become civically engaged in resilience issues.
- Community members work with resilience practitioners to identify their vulnerabilities to environmental hazards and co-produce preparedness, adaptation, and mitigation strategies to reduce those vulnerabilities.

LONG-TERM OUTCOMES

- Communities are more engaged with each other in building resilience and developing solutions that utilize scientific knowledge and reflect the values of society.
- Diverse community members are civically engaged, make informed contributions to resilience decisions, and help practitioners implement equitable adaptation and mitigation strategies.

ELP OUTCOME

Resilience policy decisions and implemented preparedness, adaptation, and mitigation strategies incorporate the values of society, improve community health, and bolster socioeconomic equity.

CAUSAL PATHWAY 4: UNDERSTANDING CULTURAL AND HISTORICAL CONTEXT OF PLACE BUILDS SOCIAL COHESION

ELP PROJECT INTERVENTIONS

ELP-funded projects integrate relevant historical, cultural, local and traditional knowledge to build social cohesion among community members.

SHORT-TERM OUTCOMES

- Community members (regardless of age) share their own lived experiences about local impacts of climate change and extreme weather, and learn about historical impacts, including impacts on socially important customs and institutions.
- Children and youth learn from older adults within their community about local impacts of climate change and extreme weather events and use storytelling and other arts to share that knowledge with others.
- Community members learn about the intersection of local social, economic, and political history as it relates to natural resources that are important to their community.
- Community members learn that there are different types of knowledge that are all important in building community resilience, in particular, indigenous knowledge and cultural practices.

MID-TERM OUTCOMES

- Community members are able to apply knowledge gained about traditional resilience practices and the impacts of climate change on socially important customs and institutions to make more culturally relevant decisions in resilience planning.
- Community members develop an appreciation for different types of knowledge, and have a more expansive picture of their community and who it includes.
- Community members develop empathy for others related to the impacts that climate change and extreme weather have had and will have on them.
- Community members develop an understanding of legacies of systemic and historical marginalization of certain groups, and the resulting unequal distribution of environmental impacts within a community.

LONG-TERM OUTCOMES

- Community members feel more closely connected to other members of the community despite generational, socioeconomic, and/or ethnic differences.
- Diverse community members have engaged in the development and support of resilience plans and practices.
- Resilience plans and practices have integrated traditional and local knowledge and address equity issues.

ELP OUTCOME

Communities are more socially cohesive and implement resilience plans and practices that are more culturally relevant and represent diverse community values.

CAUSAL PATHWAY 5: STUDENT-DRIVEN ACTION PROJECTS IMPLEMENT RESILIENCE MEASURES

ELP PROJECT INTERVENTIONS

ELP-funded projects support the creation and implementation of student-driven resilience action projects.

SHORT-TERM OUTCOMES

- Educators understand how to use a curriculum and integrate relevant, credible data to guide their exploration of locally relevant environmental hazards.
- Students follow a curriculum that guides their exploration of locally relevant environmental hazards including investigation of local and state resilience plans.
- Educators and students participate in active learning experiences (e.g., vulnerability assessments and citizen science) that help them identify and understand place-based environmental hazards and their impacts.
- Educators and students understand shorter-term preparedness actions and longer-term solutions, and the trade-offs between different solutions, to the identified environmental hazards.
- Educators and students understand uneven exposure to environmental hazards and unequal access to resources within their communities.
- Educators and students identify resilience action projects that address the environmental hazard(s) of their concern[13].
- Educators and students apply knowledge and skills to create an implementation plan for their student-driven resilience action projects[14].
- Local experts and community members are engaged and help with the development of student-driven resilience action projects.

MID-TERM OUTCOME

Educators and students work with local experts and community members to implement their action projects that aim to reduce vulnerabilities through short-term preparedness and long-term mitigation and adaptation strategies that may produce other co-benefits.

[13] This outcome is predicated on at least one of the first four short-term outcomes being achieved.

[14] This outcome is predicated on at least one of the first four short-term outcomes being achieved.

LONG-TERM OUTCOMES

- The action projects build confidence, skills and knowledge in the students and their educators that they apply in new situations.
- There is greater social cohesion within communities as a result of community members interacting with one another.
- Vulnerability to the identified hazards is reduced in a community, particularly for the most vulnerable members of that community.
- Student-driven action projects improve community health.
- Student-driven action projects and community engagement build more support for resilience plans and practices.
- Students and educators are hopeful that their community will be more resilient.

ELP OUTCOME

Educators and students have taken actions that reduce their community's vulnerability to the identified environmental hazard(s), making a positive impact on their community and providing a model for other members of their community to follow.

CAUSAL PATHWAY 6: YOUTH SUMMITS EMPOWER AGENTS OF CHANGE

ELP PROJECT INTERVENTIONS

ELP-funded projects host youth summits and facilitate other youth leadership opportunities.

SHORT-TERM OUTCOMES

- Youth represent the diversity of the communities in which they live.
- Youth conduct vulnerability assessments of their community or school and participate in local hazard-resilience tours.
- Youth and associated educators prepare for, and participate in, youth summits and other leadership opportunities.
- Youth and educators learn from scientists and government officials about the science behind climate change and other environmental hazards facing their communities and what short-term preparations and long-term solutions can be taken to address risks and impacts.
- Youth and educators know how to access and apply relevant credible data related to local environmental hazards.
- Youth learn about resilience plans that govern their community and are exposed to opportunities to partner with resilience practitioners and government officials.
- Youth develop their understanding and communication skills and build confidence through presenting to one another, working in teams, and discussing among one another.
- Youth gain an understanding of what is unique about their community and how their local economy and culture may be impacted by climate change[15].

MID-TERM OUTCOMES[16]

- Educators of youth have increased knowledge and confidence to teach about climate change and other local environmental hazards.
- Educators serve as mentors to youth pursuing community resilience leadership opportunities.

[15] This outcome occurs after the others above it, but there is no other order of occurrence among these short-term outcomes.

[16] These mid-term outcomes occur in the order they are listed here. The first outcome in the list is a necessary precondition for the others at this level.

- Youth, along with their educators, understand their community's disparate social and economic vulnerabilities to climate change and other environmental hazards, and can connect these vulnerabilities to systemic societal challenges.
- Youth, along with their educators, make informed decisions related to extreme weather preparedness and climate change adaptation and mitigation.
- Youth see themselves as climate leaders in their school and community.
- Youth, along with their educators, build social cohesion by connecting with peers who share similar concerns.
- Youth, along with their educators, communicate with their peers, families, and elected officials about community resilience issues.
- Youth are viewed as partners in achieving resilience by community leaders.

LONG-TERM OUTCOMES

- Youth leaders are hopeful about their community's future and understand the progress that can be made to address climate change and other environmental hazards.
- Youth lead on climate and other environmental issues and champion equitable community resilience through their civic participation.
- Youth leadership actions build more community support for resilience plans and practices.
- Diverse youth perspectives are included in community resilience plans.

ELP OUTCOME

Youth act as agents of change to increase resilience in their community.

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Appendix A: Glossary

Active learning: A process whereby learners engage in activities, such as reading, writing, discussion, or problem solving that promote analysis, synthesis, and evaluation of information. Cooperative learning, problem-based learning, and the use of case methods and simulations are some approaches that promote active learning (Center for Research on Learning and Teaching 2020, http://www.crlt.umich.edu/tstrategies/tsal).

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC 2018, https://www.ipcc.ch/sr15/chapter/glossary/).

Adaptive capacity: The ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change (U.S. Climate Resilience Toolkit 2020, https://toolkit.climate.gov/content/glossary).

Civic engagement: Working to make a difference in the civic life of our communities and developing the combination of knowledge, skills, values and motivation to make that difference. It means promoting the quality of life in a community, through both political and non-political processes (Ehrlich, 2000, vi, https://eric.ed.gov/?id=ED439659).

Citizen science: A form of open collaboration in which individuals or organizations participate voluntarily in the scientific process in various ways, including: (A) enabling the formulation of research questions; (B) creating and refining project design; (C) conducting scientific experiments; (D) collecting and analyzing data; (E) interpreting the results of data; (F) developing technologies and applications; (G) making discoveries; and (H) solving problems (from the Crowdsourcing and Citizen Science Act, a section of Public Law 114–329, https://www.congress.gov/114/plaws/publ329/PLAW-114publ329.pdf).

Community: A community can be defined as a system of systems, including natural, built, and social systems, as well as governmental and economic systems, that sustain and shape our lives (NAAEE 2017, 10, https://naaee.org/eepro/resources/community-engagement-guidelines).

Community-based organizations: Organizations that are driven by community residents in all aspects of their existence. This means that: the majority of the governing body and staff

consists of local residents; the main operating offices are in the community; the priority issue areas are identified and defined by residents; solutions to address priority issues are developed with residents; and program design, implementation, and evaluation components have residents intimately involved in leadership positions (National Community–Based Organization Network 2011, https://sph.umich.edu/ncbon/whatis.html).

Community resilience education: Educational approaches that develop community-level environmental literacy to understand threats and implement solutions that build resilience to extreme weather, climate change, and other environmental hazards. Environmental literacy here includes the knowledge, skills, and confidence to: (1) reason about the ways that human and natural systems interact globally and locally, including the acknowledgement of disproportionately distributed vulnerabilities; (2) participate in civic processes; and (3) incorporate scientific information, cultural knowledge, and diverse community values when taking action to anticipate, prepare for, respond to, and recover from environmental hazards, including mitigating and adapting to climate change.

Community science literacy: The capacity of a community to apply, do, and even guide science in ways that advance community priorities. It is a shared capacity, and it depends on and relates to the science learning of individuals as well as the connections, networks and agency that are distributed throughout the community (National Academies of Sciences, Engineering, and Medicine 2019, https://doi.org/10.17226/25183).

Climate change: Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system (USGCRP 2020, https://www.globalchange.gov/climate-change/glossary).

Climate justice: Ensuring that the people and communities who are least culpable in the warming of the planet, and most vulnerable to the impacts of climate change, do not suffer disproportionately as a result of historical injustice and disinvestment. Climate justice requires leaders to acknowledge that frontline communities are experts in creating solutions to protect and preserve our air, water, land, and communities, despite their historical exclusion from decision-making and from public resources and services. Climate justice requires leaders to provide public resources and services to frontline communities to engage and assist them in developing technologies, policies, professions, services, and projects for addressing the causes and impacts of climate change and healing from historical injustices (Adapted from The Greenlining Institute report Making Equity Real in Climate Adaptation and Community

Resilience Policies and Programs 2019, https://greenlining.org/wp-content/uploads/2019/08/Making-Equity-Real-in-Climate-Adaption-and-Community-Resilience-Policies-and-Programs-A-Guidebook-1.pdf).

Climate literacy: An understanding of your influence on climate and climate's influence on you and society. A climate-literate person understands the essential principles of Earth's climate system, knows how to assess scientifically credible information about climate, communicates about climate and climate change in a meaningful way, and is able to make informed and responsible decisions with regard to actions that may affect climate (USGCRP 2009, https://downloads.globalchange.gov/Literacy/climate_literacy_highres_english.pdf).

Education: The process by which individuals develop their knowledge, values, and skills. Education encompasses both teaching and learning (NOAA Education Strategic Plan 2015-2035, adapted from The Definitions Project, http://www.definitionsproject.com/).

Environmental justice: The fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no one group of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal environmental programs and policies. Meaningful involvement means that: (1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the decision-makers seek out and facilitate the involvement of those potentially affected (US Environmental Protection Agency 2020, https://www.epa.gov/environmentaljustice).

Environmental literacy: The possession of knowledge and understanding of a wide range of environmental concepts, problems, and issues; cognitive and affective dispositions toward the environment; cognitive skills and abilities; and appropriate behavioral strategies to make sound and effective decisions regarding the environment. It includes informed decision making both individually and collectively and a willingness to act on those decisions in personal and civic life to improve the well-being of other individuals, societies and the global environment (adapted from Hollweg et al. 2011, https://naaee.org/our-work/programs/environmental-literacy-framework).

Nominal environmental literacy indicates a person able to recognize many of the basic terms used in communicating about the environment and able to provide rough, if unsophisticated, working definitions of their meanings. Persons at the nominal level are developing an awareness and sensitivity towards the environment along with an attitude of respect for natural systems and concern for the nature and magnitude of human impacts on them. They also have a very rudimentary knowledge of how natural systems work and how human social systems interact with them.

Functional environmental literacy indicates a person with a broader knowledge and understanding of the nature of and interactions between human social systems and other natural systems. They are aware and concerned about the negative interactions between these systems in terms of at least one or more issues and have developed the skills to analyze, synthesize, and evaluate information about them using primary and secondary sources. They evaluate a selected problem/issue on the basis of sound evidence and personal values and ethics. They communicate their findings and feelings to others. On issues of particular concern to them, they evidence a personal investment and motivation to work toward remediation using their knowledge of basic strategies for initiating and implementing social or technological change.

Operational environmental literacy indicates a person who has moved beyond functional literacy in both the breadth and depth of understandings and skills who routinely evaluate the impacts and consequences of actions; gathering and synthesizing pertinent information, choosing among alternatives, and advocating action positions and taking actions that work to sustain or enhance a healthy environment. Such people demonstrate a strong, ongoing sense of investment in and responsibility for preventing or remediating environmental degradation both personally and collectively, and are likely to be acting at several levels from local to global in so doing. The characteristic habits of mind of the environmentally literate are well ingrained. They are routinely engaged in dealing with the world at large (Roth 1992, 26, https://files.eric.ed.gov/fulltext/ED348235.pdf).

Exposure: The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards (U.S. Climate Resilience Toolkit 2020, https://toolkit.climate.gov/content/glossary).

Extreme weather: A weather event that is rare at a particular place and time of year, including, for example, heat waves, cold waves, heavy rains, periods of drought and flooding, and severe storms (USGCRP 2020, https://www.globalchange.gov/climate-change/glossary).

Frontline communities: Frontline communities are those that experience continuing injustice—including people of color, immigrants, people with lower incomes, those in rural areas, and indigenous people—due to a legacy of systemic, largely racialized, inequity that influences their living and working places, the quality of their air and water, and their economic opportunities (The Greenlining Institute report Making Equity Real in Climate Adaptation and Community Resilience Policies and Programs 2019, https://greenlining.org/wp-content/uploads/2019/08/Making-Equity-Real-in-Climate-Adaption-and-Community-Resilience-Policies-and-Programs-A-Guidebook-1.pdf).

Geographic literacy: The understanding of human and natural systems, geographic reasoning, and systematic decision-making (National Geographic Society 2020, https://www.nationalgeographic.org/media/what-is-geo-literacy/).

Hazards: An event or condition that may cause injury, illness, or death to people or damage to assets (U.S. Climate Resilience Toolkit 2020, https://toolkit.climate.gov/content/glossary).

Impacts: Effects on natural and human systems that result from hazards. Evaluating potential impacts is a critical step in assessing vulnerability (U.S. Climate Resilience Toolkit 2020, https://toolkit.climate.gov/content/glossary).

Knowledge co-production: The collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem (Armitage et al. 2011, https://doi.org/10.1016/j.gloenvcha.2011.04.006).

Logic model: A graphic depiction (road map) that presents the shared relationships among the resources, activities, outputs, outcomes, and impact for your program. It depicts the relationship between your program's activities and its intended effects (Centers for Disease Control and Prevention, Program Performance and Evaluation Office 2018, https://www.cdc.gov/eval/logicmodels/index.htm).

Mitigation: Measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide from the atmosphere (USGCRP 2020, https://www.globalchange.gov/climate-change/glossary).

NOAA assets: Resources, services, or sites that are used to support NOAA's mission and to communicate NOAA research, data, information, and knowledge to the public. These include

education materials and programs, datasets and visualizations, subject matter experts, facilities, and managed natural resource areas.

Resilience: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment (USGCRP 2020, https://www.globalchange.gov/climate-change/glossary).

Resilience plans: For the purposes of this theory of change, resilience plans may include climate action plans, climate adaptation plans, hazard mitigation plans, sustainability plans, climate resilience plans, among others.

Resilience practitioner: Professionals charged with producing and/or implementing resilience plans.

Risk: The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence (IPCC 2018, https://www.ipcc.ch/sr15/chapter/glossary/).

Scientific literacy: The ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies of:

- Explaining phenomena scientifically - Recognising, offering and evaluating explanations for a range of natural and technological phenomena.
- Evaluating and designing scientific enquiry - Describing and appraising scientific investigations and proposing ways of addressing questions scientifically.
- Interpreting data and evidence scientifically - Analysing and evaluating data, claims and arguments in a variety of representations and drawing appropriate scientific conclusions (OECD 2018, https://doi.org/10.1787/b25efab8-en).

Social capital: The social networks and connectivity among groups and individuals within a community. This includes levels of trust and reciprocity, political engagement, length of residence, volunteerism, religious affiliation, and community organizations and services. Also

included is the feeling of belonging to and a sense of place about the community (NASEM 2019, 14, https://doi.org/10.17226/25383).

Social cohesion: Social cohesion refers to the extent to which groups and communities cooperate, communicate to foster understanding, participate in activities and organizations, and collaborate to respond to challenges (e.g., a natural disaster or disease outbreak) (NASEM 2014, 34, https://doi.org/10.17226/18831).

Social-ecological resilience: The capacity of a social-ecological system to continually change, adapt, or transform so as to maintain ongoing processes in response to gradual and small-scale change, or transform in the face of devastating change (Folke, Colding, and Berkes 2001, https://doi.org/10.1017/CBO9780511541957).

Social learning: Ongoing, adaptive process of knowledge creation that is scaled up from individuals through social interactions fostered by critical reflection and the synthesis of a variety of knowledge types, that result in changes in social structures (e.g., organizational mandates, policies, social norms) (Sharpe et al. 2019, 44, https://doi.org/10.13140/RG.2.2.31730.25285).

Theory of change: Approaches that articulate an ultimate 'big picture' outcome, and then 'backwards map' the steps needed to achieve it. In other words, the stakeholders begin with defining the long-term goal, and work backwards in time up to the present, systematically laying out each step along a 'causal pathway.' For each step in the sequence, stakeholders outline clear indicators, thresholds, and assumptions. The end result is usually a diagram ('change map'), accompanied by a narrative. Theory of change is also an iterative process; in other words, the strategy would be reviewed regularly and modified to reflect emerging conditions and new knowledge (Bours, McGinn, and Pringle 2014, 2, https://ukcip.ouce.ox.ac.uk/wp-content/PDFs/MandE-Guidance-Note3.pdf).

Uncertainty: An expression of the degree to which future climate is unknown. Uncertainty about the future climate arises from the complexity of the climate system and the ability of models to represent it, as well as the inability to predict the decisions that society will make. There is also uncertainty about how climate change, in combination with other stressors, will affect people and natural systems (USGCRP 2020, https://www.globalchange.gov/climate-change/glossary).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm

and lack of capacity to cope and adapt (IPCC 2018, https://www.ipcc.ch/sr15/chapter/glossary/).

Youth: Persons between the ages of 15 and 24 years old (United Nations 2020, https://www.un.org/en/sections/issues-depth/youth-0/).