COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE	☐ Special Exception to Deadline Date Policy	FOR NSF USE ONLY
NSF 22-633 01/24/2023		NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) **OIA - EPSCoR RII Track-2 FEC**		**2316271**

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TITLE OF PROPOSED PROJECT
RII Track-2 FEC: Community-Driven Coastal Climate Research & Solutions (3CRS) for the Resilience of New England Coastal Populations

SHOW LETTER OF INTENT ID IF APPLICABLE: L02621130

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 5,999,025	48 months	09/01/2023	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
- ☐ BEGINNING INVESTIGATOR
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES
- ☐ PROPRIETARY & PRIVILEGED INFORMATION
- ☐ HISTORIC PLACES
- ☐ VERTEBRATE ANIMALS IACUC App. Date ______ PHS Animal Welfare Assurance Number ______
- ☒ TYPE OF PROPOSAL Research
- ☐ HUMAN SUBJECTS Human Subjects Assurance Number ______ Exemption Subsection ______ or IRB App. Date ______
- ☐ FUNDING OF INT'L BRANCH CAMPUS OF U.S IHE
- ☐ FUNDING OF FOREIGN ORGANIZATION OR FOREIGN INDIVIDUAL
- ☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED ______
- ☒ COLLABORATIVE STATUS A collaborative proposal from one organization (PAPPG II.D.3.a)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
DEPT OF EARTH ENVIR & PLANETA	324 Brook St Box 1846 Providence,RI 02912 US
PI/PD FAX NUMBER	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME: Emanuele Di Lorenzo	PhD	2003	401-863-1000	manu.ocean@brown.edu
CO-PI/PD: James M Pringle	PhD	1998	603-862-5000	jpringle@unh.edu
CO-PI/PD: Anabela M Resende da Maia	PhD	2011	401-456-9071	aresendedamaia@ric.edu
CO-PI/PD: Austin Becker	PhD	2013	401-874-4192	abecker@uri.edu
CO-PI/PD: David Reidmiller	PhD	2010	228-207-1695	dreidmiller@gmri.org

Letter of Intent: L02621130, SBE, Coastline and People

Overview

Low-lying, working waterfront communities throughout New England (NE), like others around the U.S. whose economies and populations rely on ocean resources, are disproportionately vulnerable to risks from climate change. Large parts of these communities, including critical infrastructure, are projected to be increasingly impacted by nuisance flooding and permanently underwater by the end of the century. Many NE coastal communities are socially and economically disadvantaged, having high levels of poverty, limited access to healthcare, inadequate infrastructure, high reliance on natural resources, increased taxes and living costs, and a limited capacity to adapt to the changing climate. Decision-makers need to understand and manage the unique needs and challenges faced by working waterfront communities as they develop climate adaptation strategies and solutions for coastal resilience. By collaborating with four strategically selected NE pilot communities, this project aims to *co-develop a scalable and transferable framework for **Community-Driven Coastal Climate Research & Solutions** (**3CRS**) that builds together the processes, expert networks, data streams, local relationships and knowledge that are necessary to expand a shared capacity of NE working water-dependent communities to become more resilient to climate change with a focus on the health and social-economic dimensions.*

Intellectual Merit

Leveraging existing relationships within the NE pilot communities, 3CRS will address three key research challenges for climate resilience planning. ***Challenge 1:*** Identify and measure "dynamic" changes in human health and wellbeing, habitability, environment, and other climate vulnerabilities. ***Challenge 2:*** Downscale climate models to the spatiotemporal scale of communities and project the climate resilience impacts for planners. ***Challenge 3:*** expand the capacity to incorporate data, knowledge, and expert networks into community resilience planning processes. Through a series of collaborative community structures and processes, 3CRS will develop a *Community Knowledge Collective* based on the co-production of three primary knowledge streams that span observational **DATA**, community-driven **METRICS** of resilience with a focus on health and socioeconomic dimensions, and climate adaptation **NARRATIVES** (**People & Data** phase). These streams will be processed through a hierarchical set of modeling and comparative analysis approaches (**Data & Knowledge Processing** phase) that expand the *Community Knowledge Collective* into a *Synthesis*. As part of this phase, a novel *New England-wide Coastal Hazards Analysis Modeling and Prediction System* (**NE-CHAMP**) will be deployed to enable communities to visualize and analyze the impacts of present and future climate on critical infrastructure, health, social-economic, and other community-driven resilience **METRICS**. The NE-CHAMP will also be used to inform community climate dashboards and conduct evaluations of climate scenarios with the pilot communities to evolve the **NARRATIVES** into visioning storylines for future climate adaptation (**People & Solutions** phase). In this last phase of the project, a series of shared resilience roadmaps will be produced that digitally document the transferable processes for developing coastal adaptation strategies to scale, including tools and expert networks, through sharing across communities.

Broader Impacts

(1) Mentorship and Advancement of Early Career Scientists. The project team (55% women, 45% men) will mentor and advance six early career researchers and assistant professors (4 women, 1 man, 1 women with disability), 5 postdocs across institutions, and four graduate students. ***(2) Infrastructures that Increase Capacity for Resilience of Working Water-dependent Communities.*** The project will co-design with the pilot communities eight infrastructure deliverables that expand existing NE efforts and institutions, and that are scalable and applicable to other regions. They include: coastal ocean observing system **(D1-2)**, the NE-CHAMP modeling & analysis tools **(D3-D4)**, planning (e.g., roadmaps, adaptation storylines), **(D5-6)**, training **(D7)**, and human **(D8)**. While these infrastructure elements are developed with our pilot communities, they are co-designed to be scalable and applicable to other regions. ***(3) Training and Building Expert Capacity in Local Communities***. On-demand training materials, including a *Community Resilience Training Module* and *Local Decision Makers Boot Camps* will be developed together with 6-12 Education Modules. Graduate & undergraduate students and postdocs will be mentored for science and education careers. ***(4) International Efforts for Coastal Resilience under the UN Ocean Decade.*** The 3CRS framework will be shared as a US pilot contribution to the coastal resilience efforts of the *Global Ecosystem for Ocean Solutions* UN Ocean Decade Program under the SEAT'IES project and in coordination with the UN Decade Center for Coastal Resilience.

TABLE OF CONTENTS

For font size and page formatting specifications, see PAPPG section II.B.2.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

1. Status and Overview

Low-lying, working waterfront communities throughout New England (NE) (**Figure 1**), like others around the U.S. whose economies and populations rely on ocean resources, are disproportionately vulnerable to risks from climate change (e.g., Carey 2021). These communities benefit from thriving blue economies based on industries such as shipping, fishing, and tourism. Emergent industries (e.g., aquaculture, offshore wind) present new opportunities, but also new exposure to climate-related risks. NE has over 6,000 miles of tidal coastline and many communities lack governance structures to cope with imminent climate impacts, such as coastal flooding from sea level rise, storm surge, and extreme precipitation, as well as heatwaves, droughts, and rapidly evolving ecosystems. By 2050, NE is likely to see between 1.1 and 1.8 feet of relative sea level rise, potentially 3 to 4.6 feet by 2100, inundating land and critical infrastructure in working waterfront communities (**Figure 1**). Just a one-foot increase in sea level will lead to a 15-fold increase in the frequency of "nuisance" flooding (MCC STS 2020, Fox-Kemper et al. 2021). The Gulf of Maine has recently warmed faster than 99% of the global ocean, shifting commercially valuable fish species (Pershing et. al 2015). These impacts threaten the economic viability, population health, and habitability of coastal communities (Dupigny-Giroux et al. 2018). As the most rural U.S. state, 72% of Maine's coastal municipalities have no town planner on staff and no regional planning support; RI is an urban state without a port authority to plan. Failure to monitor the impacts of climate change and develop informed adaptation plans means that working waterfront communities may disappear (e.g., Coombs 2020; USGCRP 2018).

<u>The goal of this project long-term</u> is to *co-develop a scalable, transferable framework for **Community-Driven Coastal Climate Research & Solutions** (**3CRS**) that builds together the processes, expert networks, data streams, local relationships and knowledge that are necessary to expand a shared capacity of NE working water-dependent communities to become more resilient to climate change with a focus on the health and social-economic dimensions.*

Central to the 3CRS is the National Research Council (2012) definition of resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" or risk . Risk is the "potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems" (IPCC 2022). Risk has three elements – hazard, vulnerability, and exposure – each of which are subject to climatic and socio-economic forces (Reisinger et al. 2020). To be resilient, communities can manage risk by either reducing the hazard directly (i.e., emitting less greenhouse gasses), reducing exposure (e.g., by infrastructure improvements) or reducing vulnerability (e.g., by improving healthcare or economic conditions: USGCRP 2018). 3CRS will bolster adaptive capacity in working waterfront communities by using community-driven approaches to reduce exposure and vulnerability (Bhattachan et al. 2018).

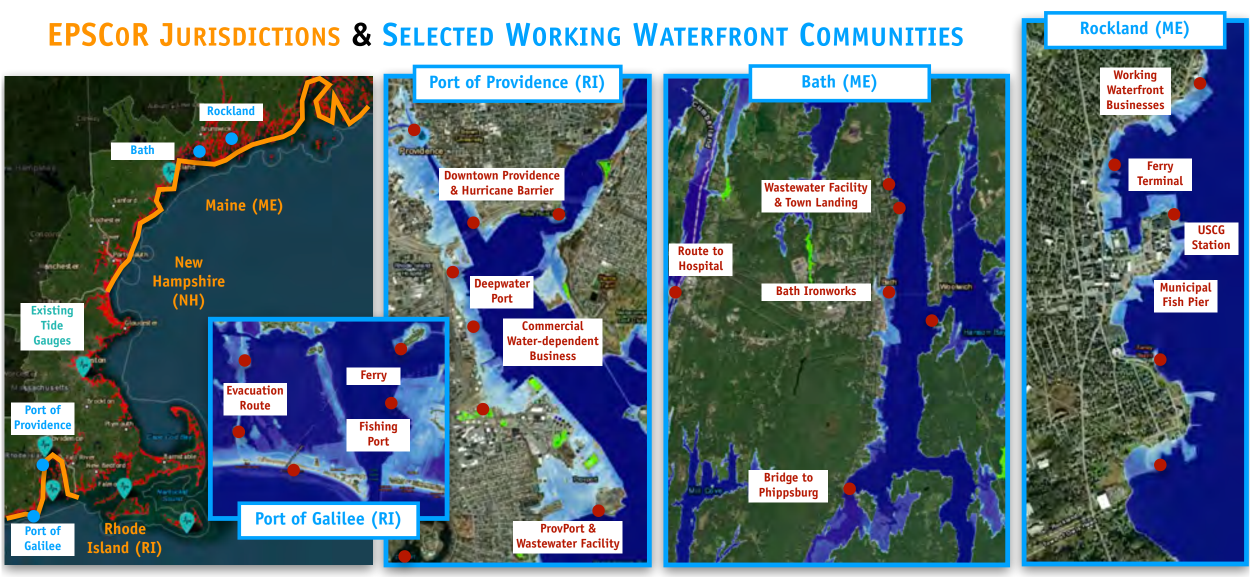


Figure 1 Flooding Area (5ft water level) Sensor Locations Draft (e.g., Water-level, Air-Quality, Temperature)

Target populations. While our goal is to expand climate resilience in populations along the entire New England coast and beyond, our project will co-develop the 3CRS framework with a few pilot communities. We selected one industrial port and one commercial fishing port each in Rhode Island (RI) and Maine (ME): the **Port of Providence (City of Providence, RI)**, the **Port of Galilee (Town of Narragansett, RI), Rockland (City of Rockland, ME)** and **Bath (Town of Bath, ME)** (**Figure 1**). 3CRS builds on existing relationships to deepen community involvement in climate risk awareness, climate science literacy, and mainstreaming climate considerations into decision-making. The working waterfront communities are a portion of a larger municipality, including people and groups whose livelihood, property, and/or business connects them with the coast; they are delimited flexibly (e.g., identity distinctions) to exemplify economic and social aspects missing from conventional risk assessments. (see **section 3.1**)

Challenge & Aim 1: Identify and measure "dynamic" changes in human health and wellbeing, habitability, environment, and other climate vulnerabilities. Climate vulnerabilities, including the high priority areas of human health and residential habitability, have local dimensions that are not known *a priori*. For example, climate change and attributed extremes affect human health via thermal stress, infectious disease and microbial proliferation, injuries and fatalities during extreme weather, and impaired nutrition due to changes in crop, livestock, and fisheries yields (McMichael et al. 2006). Sea level rise and more frequent and intense coastal storms also have the potential to diminish livelihoods, damage vital infrastructure and drive population migration (Hauer et al. 2020). All of these manifest in locally specific ways. The 3CRS will collect local knowledge and identify measures of these threats to investigate key social science questions that affect adaptive capacity: **(Q1)** *How do climate change impacts exacerbate existing health and residential vulnerabilities in working waterfront communities, and how can they be measured?* **(Q2)** *How can we merge qualitative data from community meetings and quantitative health and population data with environmental models and hyper-local data into "dynamic" (e.g., space-time-varying) resilience metrics?* This community-level data will help community prepare for climate change.

Challenge & Aim 2: Downscale climate models to the spatiotemporal scale of communities and project the climate resilience impacts for planners. Even with a clear and specific understanding of community vulnerabilities, raw climate model projections are not trustworthy on the space and time scales needed. The IPCC Atlas (Gutiérrez et al. 2021) does not distinguish Florida from RI, NH, and ME in projections, while the USGCRP National Climate Assessment combines RI, NH, and ME. Furthermore, the timescales over which climate projection analysis is easily carried out (e.g., by 2050, by 2100) are not the same as community needs (e.g., a 30-year mortgage or a mayoral election cycle). This lack provokes key research questions such as: **(Q3)** *What uncertainties do different methods of downscaling bring?* **(Q4)** *How are the unlikely events that are absent from the historical record, but intensely damaging, to be captured?* **(Q5)** *Can data-driven models close the gap between physical variables and health and social risks?* In coastal regions, coastal dynamical models and regional climate models can address this need for higher-resolution understanding of hazards. Some are already available in our region (e.g., Wilkin et al. 2022) or even developed by our team (Sane et al. 2021). These dynamical models excel at predicting the physical and biological variables that circumscribe the model state, however, they are not designed to predict many aspects of societal and environmental concern. Novel modeling in this project will extend into societally-important or unmodeled outcomes, following machine learning methods in the last IPCC assessment (Fox-Kemper et al. 2021). We will develop a multivariate hyper-local sensor network and a collection of high-resolution climate model outputs to address community-identified scenarios and timescales of interest. This approach is fundamentally probabilistic, exploiting model ensembles.

Challenge & Aim 3: Expand the capacity to incorporate data, knowledge, and expert networks into community resilience planning processes. Data and understanding of climate change are often remote for the decision-making processes and resilience planning (Reiblich et al, 2017). For example, federal agency data is not readily accessible or easy to understand. News media, even those with an environmental focus, struggle to find relevant data and attribution to climate change. Improving communication, visualization, and co-discovery of specific data needs can help bridge this gap so that community members can make informed decisions. **(Q6)** *What are best practices for science-informed community-driven resilience planning?* Our project will exemplify co-developed roadmaps to navigate these data and information challenges toward community resilience by connecting relevant data streams, community knowledge and links to adequate expert networks.

2. Results from Relevant Prior Support

NSF EPSCoR RII Track-1: Rhode Island Consortium for Coastal Ecology Assessment, Innovation, and Modeling (RI C-AIM), **#OIA-1655221, 8/1/17-7/31/23, $19M, CoPI Maia**. *Intellectual Merit:* RI C-AIM aims to understand how climate variability impacts coastal ecosystem biology and to create models predicting ecological changes through biocomplexity. *Broader Impacts:* Jurisdictional capacity was increased through creation of an Integrated Bay Observatory and three new shared core facilities (Aquatic Studio at PC, RI Consortium for Nanoscience and Nanotechnology (RIN2) at URI, Leduc imaging facility at Brown) and supporting existing EPSCoR-affiliated shared facilities (Marine Science Research Facility at URI, Center for Computational Visualization at Brown, The Nature Lab at RISD), and providing technical and professional skills training to over 400 undergraduate and graduate students. As of May 31, 2022, it has published 139 papers, received over $43.9M in external funding, and led to the hiring of 12 successful faculty members. Our Diversity Plan led to inclusive recruiting and training (e.g., >60% women graduate students, >20% URM undergraduates).

NOAA Coastal Ocean Program: The Georgia Coastal Equity and Resilience Hub, #NA22NOS4690219 09/01/2022-30/08/2027, $955K, Co-PI Di Lorenzo. *Intellectual Merit:* Funded through a $5M congressional earmark, this project is co-developing with local decision makers a high resolution modeling and forecasting system for water-level along the entire Georgia coast to enable the study of extreme events and climate change. The modeling system is informed and validated through high spatial resolution observations provided by a smart sea-level sensor network, which this project is also expanding geographically over the entire Georgia coast. *Broader Impacts:* This project establishes strong partnerships between researchers, social justice community organizations, local decision makers, and military to co-design and deploy the tools and knowledge that enable the development of equitable coastal adaptation and development strategies.

NOAA Office of Education, Environmental Literacy Program: Community Resilience Informed by Science and Experience (C-RISE), #NA15SEC0080006 10/01/15-09/30/19, $499K, Co-PI Reidmiller. *Intellectual Merit:* C-RISE aimed to build the capacity for community resiliency planning and adaptation actions. Working with an advisory group including representatives from NOAA, Maine Geological Survey, Maine Department of Environmental Protection, and the cities of Portland and South Portland we developed public programming that provided participants with knowledge of and access to local sea level rise data. *Broader Impacts:* GMRI staff facilitated over 60 community events in over 30 coastal communities in Maine, reaching over 2,000 individuals. Program evaluation indicated that participants discussed flooding issues with their families, friends, and neighbors, further examined local sea level rise maps, and engaged with community decision-makers about resiliency planning. Building on this grant GMRI received a new NOAA grant for **Rural Coastal Community Resilience Training, $449K**

NSF Basin Scale forcing of flows on western-boundary shelves, #1459609 (6/2015-8/2021) $369,663, Co-PI Pringle. *Intellectual Merit:* We found that deep ocean forcing affects western boundary shelf flows, but local wind and buoyancy forcing dominate on broader shelves; glacial canyons and sub-mesoscale instabilities also play a role in reducing deep ocean forcing effects. The flows interact with other coastal flows, particularly in the nearshore(10 publications). *Broader Impact:* This work supported 2 undergraduate and 3 graduate students. This work led to interdisciplinary work on the interactions of coastal flows and species diversity in the coastal ocean and a follow-on NSF Grant (OCE1947954).

Dept. of Homeland Security Center of Excellence in Coastal Resilience, # 2015-ST-061ND0001-01 (07/01/2015 – 06/30/2023), $2.5M. Coastal Hazards, Analysis, Modeling, and Prediction System for Emergency Planning, Management, and Response, Co-PI Becker. *Intellectual Merit:* This project delivered a Hazard Consequence Modeling System that demonstrates near real-time hazard and impact prediction for hurricanes and nor'easters in Southern New England using the ADCIRC-Surge Guidance System. It integrates end-user knowledge and concerns as model inputs to predict cascading consequences of extreme weather (i.e., surge, wind, flooding, waves) impacting critical infrastructure (7 publications). *Broader Impacts:* This approach provides emergency managers and facility managers access to relevant, local-scale information about potential consequences of extreme events in advance of a storm's landfall, resulting in more efficient allocation of resources and a reduction of harm to coastal communities.

COMMUNITY-DRIVEN COASTAL CLIMATE RESEARCH & SOLUTIONS (3CRS) PROJECT

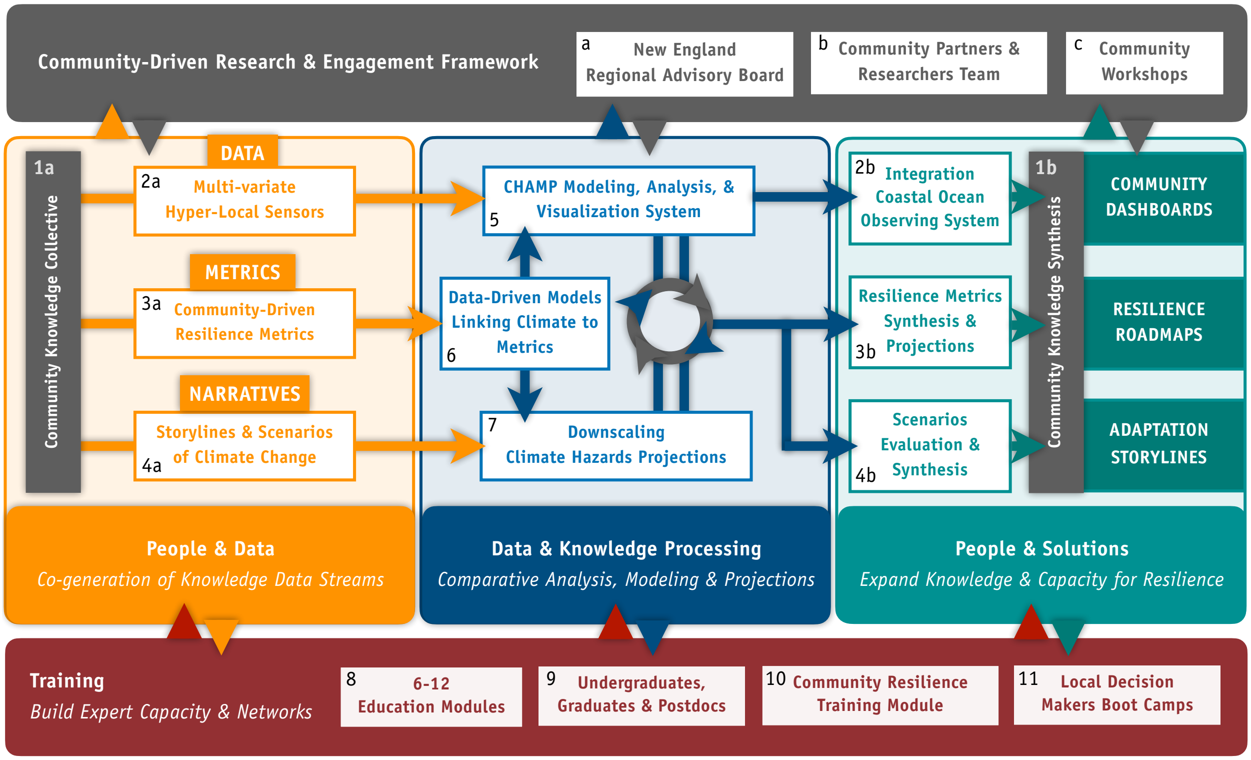


FIGURE 2 **Research TASKs** 1-7 | **Training TASKs** 8-11 | **Collaborative Structures & Mechanisms** a-c

3. Research, Collaboration, and Workforce Development

To address the **challenges** (1-3) and **questions** (1-6) introduced above, the **3CRS** will advance 7 **r**esearch and 4 workforce development **TASKs** (1-11), which are introduced by describing **Figure 2** below. This description provides a high-level overview of how numbered TASKs relate to the project. *NOTE: it is useful to keep a copy of this figure accessible while reading the proposal.*

Overview and Summary of 3CRS Project. Central to this project is the "community-driven" research, implemented through a **Research & Engagement Framework** (gray box topping **Figure 2**). This framework is composed of three collaborative structures & mechanisms detailed in **section 3.2**: ***(a)*** *Regional Advisory Board* (**RAB**: community & other local representatives), ***(b)*** *Community Partners & Researchers Team* (**CPRT**: community & co-investigators), and ***(c)*** a series of *Community Workshops* (**WS**) where researchers and key community members co-develop research metrics and synthesize outcomes (**TASK 1**). The CPRT, RAB, and WS will serve to advance community-driven research in three interconnected collaborative development phases of the 3CRS framework (**Figure 2**). Specifically the co-generation of knowledge and data streams (**People & Data** phase in orange) that will guide modeling activities (**Data & Knowledge Processing**), which will ultimately allow a synthesis of results and knowledge to co-develop and co-deploy resilience strategies and tools for resilience planning in the selected communities (**People & Solutions**). Throughout, early career scientist training, 6-12 education modules, and expert capacity and network building will occur (**Training**).

People & Data: Co-generation of Knowledge Data Streams. Starting with a first round of workshops in each of the pilot communities (**WS1,** see description at the end of this section), the project will assemble the **CPRT** and **RAB** to begin the co-development of a ***Community Knowledge Collective (CKC)*** that centers on community expertise and establishes a budget and fee structure to compensate community leaders and residents as experts (see **TASK 1**). Coordinated by the **CPRT** and building on the **CKC,** a second-round of workshops (**WS2**) will be organized to start three parallel research threads focused on **DATA**, **METRICS**, and **NARRATIVES** (see **Figure 2**, **Orange**). For the **DATA** thread we will co-develop and deploy a networks of community-driven, low-cost, ***Multivariate and Hyper-Local Sensors*** (**TASK 2**) to measure new data streams at the scale where people live. Given that all the pilot communities are subject to recurrent flooding and sea level rise, we will begin with co-deploying water-level sensors networks. Co-developing these sensors networks has proven to be an important mechanism for building capacities in coastal communities (see also **Section 3.3;** Di Lorenzo et al. 2022). For the **METRICS** thread, workshops will initiate the co-design of a series of ***Community-Driven Resilience Metrics*** (**TASK 3**). Other sensors will be added for tracking these metrics (e.g., temperature, air-quality, water-quality linked to wellbeing and health). These metrics will capture the impacts of climate that are important to the pilot communities and aid in monitoring and projecting patterns of change in resilience. These metrics are "everyday" indicators that communities use to reflect their concept of "resilience," essentially the capacity to take care of themselves, their family and neighbors when faced with threats to their wellbeing. While these metrics will be co-designed during the project, especially **WS1** & **WS2**, our experience working with coastal communities suggests key metrics will initially focus on measuring the impact of climate on community health, social cohesion, and place habitability (Nicohols et al. 2019; Arthurson and Baum 2013). To co-develop the resilience metrics, workshops will identify and collect key quantitative and qualitative social, demographic, and economic measures, anchored in narratives of lived experience associated with perceived climate-related risks. These experiences, knowledge and data, will inform the **NARRATIVE** thread, which aims at describing community ***Storylines & Scenarios of Climate Change*** (**TASK 4**). Identifying and sharing these narratives and storylines is a critical step for any community to plan its adaptation building its community-based vision of resilience. Our pilot communities are projected to be partially submerged by 2100; adaptation storylines will extend roughly 10-15 years while migration storylines will span 15-40 years.

Data & Knowledge Processing: Comparative Analysis, Modeling & Projections. In this phase, the **DATA**, **METRICS**, and **NARRATIVES** threads will be processed through a hierarchical set of modeling and comparative analysis approaches (**Figure 2**, **blue**). We will use existing coastal ocean and hydrological ***Impact Modeling, Analysis, & Prediction*** frameworks based on the *Coastal Hazards, Analysis, Modeling & Prediction (CHAMP)* system developed by URI (Becker et al 2021) to ingest the data streams from the sensor networks and other sources (e.g., climate models informing the scenarios & metrics developed during **WS2**) to map hazards and project climate exposures (**TASK 5**). The models already included in CHAMP cover the entire NE coast including the RI infrastructure exposure to climate hazards. CHAMP capabilities will be expanded to include the newly developed community-driven resilience metrics (**TASK 3**), starting from the pilot communities. To do so, we will develop a series of ***Data-Driven Models (ML) Linking Climate to the Resilience Metrics*** (**TASK 6**), which will allow us to extract the physical climate variables from weather reanalyses and coastal models, and quantify their impacts on probabilities of the identified community metrics. These data-driven models and metrics will be incorporated in CHAMP to produce storymaps of the resilience metrics in space and time. Based on the social and health data availability, our target is to have county-scale resolution for the pilot communities and beyond. After mapping current and past conditions, we will be ***Downscaling Climate Hazards Projections*** (**TASK 7**) from Earth System Model ensembles, producing climate storymaps of expected impacts on the resilience metrics on different time horizons (e.g., 10, 40 years). This downscaling task will inform the storylines and scenarios of climate change co-designed with the communities (**TASK 4, WS2**). Using ensembles and probabilistic downscaling allows estimation of uncertainties from natural and forced climate variability (and model errors) and attribution of impacts to climate - an approach that the climate community has recognized as critical but yet not deployed for coastal climate. Due to cost, typical coastal downscaling relies on the use of regional models forced with one climate model, downscaling 30-40 ensemble members with multiple climate models is prohibitively expensive. **TASK 7** will avoid these costs using both regional circulation dynamical models and data-driven (statistical and machine learning) approaches. Probabilities capturing the downscaled products will be merged into CHAMP to support the planning and decision-making processes.

People & Solutions: Expand Knowledge & Capacity for Resilience. The previous joint learning phases of the project are the data and model foundations for a ***Community Knowledge Synthesis*** at **WS3** & **WS4** where the initial *Community Knowledge Collective* (**TASKS 1-4**) is expanded by the modeling (**TASKS 5-7**) and comparative analyses outcomes of the **DATA**, **METRICS**, and **NARRATIVES**

threads. Specifically, for the **DATA** thread, the sensor data streams and the output of the CHAMP system will be ***Integrated*** into the ***Coastal Ocean Observing System*** (e.g., NERACOOS) (continuing **TASK 2**) and in the data streams and map layers of **Community Dashboards** of choice. For the **METRICS** thread, the data-driven modeling (**TASK 6**) will provide a ***Resilience Metrics Synthesis & Projections*** (continuing **TASK 3**), which will provide temporally and spatially explicit quantitative data on vulnerability and exposure as well as qualitative measures on community perceptions and concerns about climate change. For the **NARRATIVES** thread, storymaps from the CHAMP system and community-developed scenarios will become ***Scenarios of Change Evaluation and Synthesis*** (continuing **TASK 4**), featuring a series of **Adaptation Storylines** incorporating downscaled climate projections (**TASK 7**). The ***Community Knowledge Synthesis*** (continuing **TASK 1)** will co-develop **Resilience Roadmaps** to articulate the processes and tools that allowed us to incorporate this community co-generated knowledge and data into community-driven adaptation strategies for strengthening population resilience, as they understand it, adding capacity to adapt to climate change. The roadmaps will also link these procedures, data and processes to the necessary expert networks and human infrastructure (e.g., **RAB**), and will be open, transparent, scalable, and transferable to other communities beyond the pilot examples.

Collaborative Workshops. The 3CRS project includes a set of five workshops for each site to engage community partners and co-produce data. **WS1** will focus on generating information regarding local knowledge, values, and attitudes through an iterative process (**TASK 1**) that will also inform later workshop activities and outputs. Workshop **WS2** will build on this to develop community resilience metrics and storylines (**TASKs 2-4**); **WS3** and **WS4** will be devoted to evaluate the sensor data and dynamical model results (**TASKS 2 & 5**), community metrics (**TASKS 3 & 6**) and scenarios and future adaptation storylines of climate change (**TASKs 4 & 7**). Finally, **WS5** will finalize the community knowledge synthesis and present to a broader community the deliverables from this project (**D1-D8; Figure 3**), described in this section after the **TASKs**. The **Training TASKs 8-11** are described in **Section 3.4** and will be integrated in the workshops and benefit from the deliverables (**D1-D8; Figure 3**). To facilitate participation, we have allocated funds to support community partners to attend and engage in the workshop and training activities. A timeline for the workshops is in **Section 5, Table 3**.

EPSCoR Infrastructure Deliverables. At the end of this project we anticipate delivering eight EPSCoR infrastructures that expand the capacity for coastal resilience science and planning of coastal populations along the New England Coast and beyond, summarized in **Figure 3** (**D1-8**). While these infrastructure elements are developed with our pilot communities, they are co-designed to be scalable and applicable to other regions, and span the following types: **data (D1-2), modeling & analysis tools (D3-D4), planning (D5-6), human (D7), and training (D8)**. The 3CRS project will: **(D1)** build in collaboration with NERACOOS the foundation for the next generation of community-driven coastal observing system; **(D2)** co-develop novel dynamic metrics to measure population resilience across the social and health dimensions at the county-scale along the NE coast; **(D3)** develop a curated database of downscaled ensemble climate projections with uncertainties & probabilities for the NE coast that will be available to scientists and local stakeholders; **(D4)** expand the existing Coastal Hazards Analysis, Modeling, and Prediction System (CHAMP) from Rhode Island to Maine (to form NE-CHAMP), which enables for the

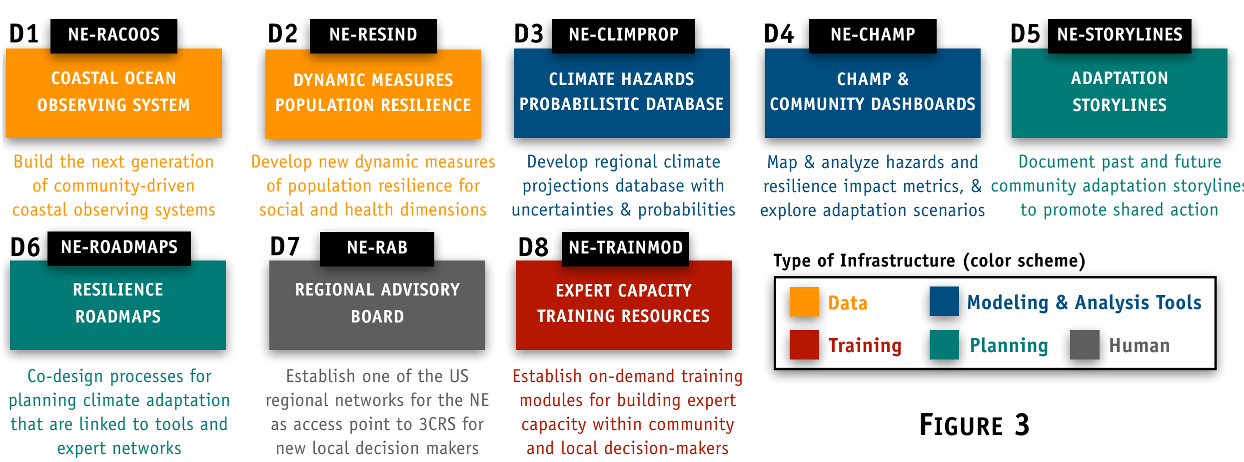


FIGURE 3

mapping and comparative analyses of key environmental variables (e.g., water-level, air-quality, temperatures, and others) both for past and future scenario conditions and in relation to the impacts on resilience metrics. NE-CHAMP products will be included in community dashboards and resilience training modules; **(D5)** document past and future community storylines that describe how populations have and are adapting to climate change. The comparison and analyses of these digital storylines is a powerful tool to promote shared action within and across communities; **(D6)** co-design a series of digital resilience roadmaps that document the best-practices and processes for developing coastal adaptation strategies that can be shared across communities, and link these processes to the necessary tools and expert networks; **(D7)** establish NE Regional Advisory Board (RAB) that will serve as access point to 3CRS framework for local decision makers along the entire NE coast. The RAB will be part of an ongoing effort led by Mayors across the US of creating a national Community of Practice (CoP) (see **section 3.2**) for coastal resilience that provide access to resources for underserved coastal communities that are being impacted by climate change. The RAB and the knowledge produced by the 3CRS will also contribute to the U.N. Ocean Decade (see **section 3.2**); **(D8)** use the 3CRS tools and knowledge to establish on-demand training modules for building expert capacity, including local decision makers, communities, and 6-12 education.

TASK 1. Community Knowledge Collective and Synthesis (Leads: Fairbanks, Acton)

Because climate vulnerabilities and exposures are localized and may include unknown dimensions, it is crucial to identify and describe them at a local level. Doing this requires direct engagement with coastal communities and the co-production of climate knowledge at the appropriate scale and with relevant societal metrics (Fleming et al. 2022). The **Community Knowledge Collective (CKC)** will bring community stakeholders, researchers, and policy decision-makers together to assemble a database around the aforementioned resilience concepts and their relevance to human health and residential habitability, exploring the perceptions and values of individuals in relation to their health and wellbeing, their property, and the systems and resources that are part of their communities' built and natural environment. More specifically, the CKC will focus on co-producing three categories of information and data: (1) Local knowledge of current community health, wellbeing, and infrastructure status, climate impacts, and related social and environmental changes (Coulthard 2012; Coulthard, Johnson and McGregor 2011); (2) Stakeholder values and attitudes about climate impacts, social and environmental changes, and their implications for individual and community futures (Boucquey et al. 2012; Murray and D'Anna 2015); and (3) information that will improve clarity about policy decision-maker needs and researcher cabilities and tools (Acton et al. 2019; Fairbanks et al. 2016; Fairbanks et al. 2018).

The CKC process will produce a **Knowledge Digital Database** from three types of data: (1) **Documents**: existing state, local, and other relevant documents that examine climate issues will be collected, reviewed, and analyzed. This will include, for instance, web-based information as well as key sources suggested by community partners at GMRI, RI CRC, and the CPRT and RAB, and will provide both data and information to identify specific research partners and informants. (2) **Workshops (WS)**: will be used to advance the CKC efforts and its synthesis phase as described in the *Collaborative Workshops* section above. (3) **Interviews:** key informants, such as community leaders or members of underrepresented groups, will be interviewed using a semi-structured interview method to elicit information on relevant topics (Bernard 2017). Interviews are useful for two reasons. First, they will be used to follow up with workshop participants to verify data and explore workshop topics in more depth (Merriam and Tisdell 2015). Second, they will be used to engage stakeholders who may otherwise be underrepresented in workshop processes, because they may be uncomfortable sharing their views in public, cannot attend during workshop times, were overlooked in early planning processes, or otherwise. We will also analyze the knowledge database to gain a deeper understanding of pilot communities' values and develop a vision for each community. This latter point is critical, as climate impacts are inherently issues of justice and equity. Ensuring we are empowering a diversity of voices – including those often unheard in policy, planning, or research processes – is essential to collect viable data and prioritize the pilot communities themselves in the 3CRS project. All qualitative data from **TASK 1** will be collected in a database and analyzed for key themes, metrics, and narratives using both deductive and inductive coding (Dryzek 1997; Roe 1994; Bernard 2017). Ultimately, the co-production of the CKC database provides a foundation for synthetic outputs in later project stages. Stakeholder input and information will be synthesized with metrics, narratives, and other project data to develop and formalize community dashboards, storylines, and roadmaps. The iterative nature of the CKC process ensures that the final outputs maintain direct relevance to community priorities and offer continual opportunities for stakeholders and project partners to provide input for data refinement and validation.

The CKC process will enable team members to identify and co-produce key climate metrics (**TASK 2, D2**) and draft community climate narratives (**TASK 4,** deliverable **D5**). These metrics and draft narratives will serve as starting points for sensor networks and modeling (**TASKS 5-7,** deliverables **D1, D3, D4**) and synthesis of modeling and community knowledge in the **People & Solutions** phase of 3CRS to produce resilience roadmaps and training modules (deliverables **D6, D8**). Furthermore, the CKC process itself is critical to project success: through engagement and co-production of data, we will develop relationships with key community stakeholders that will serve to both improve the quality of our data and to deliver durable results that will guide community resilience planning (Fleming et al 2022). In each pilot community we will engage representatives of the port and coastal industries, representatives of social organizations, and residents of the area. Some representatives may not live in the area or directly participate in coastal industries, but they nevertheless have a stake in its resiliency. We anticipate divergent interests and preferences for resilience strategies in each pilot community. Our task is identifying areas of conflict and trusted partners who can bridge divides between stakeholder groups. To build supportive relationships between the project team and community stakeholders, the project team will practice cultural competence, including reflection, awareness, and genuine interactions, recommended by the American Evaluation Association (American Evaluation Association 2011). Cultural competence is particularly important in identifying social vulnerabilities of working waterfront communities.

TASK 2. Multivariate Hyper-Local Sensors (Leads: Shyka, Di Lorenzo)

Water level, precipitation, river runoff, and morphology represent primary data streams for regional and urban-scale flooding hazards. Yet, near real-time characterization of the spatial-temporal character of water elevation and precipitation remains challenging (Cheng et al. 2007, Mcleod et al. 2018, Seo et al. 2010). This is particularly relevant for the 3CRS pilot communities. Leveraging a 2022 congressional earmark secured by the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) that supports the integration and installment of new hyper-local water-level sensor networks along the NE coast, we will co-design and deploy four sensor networks, one in each pilot community. Each network will have about 10-15 low-cost acoustic water-level sensors that are operated by batteries (4-year lifespan). The sensors will be connected via LORAN wireless to 3-4 hard-wired base stations connected to the internet. NERACOOS will lead the technical aspects of the installation and operations, while the project team and CPRT will bring the community-driven design of the network. Based on previous experience by the PI Di Lorenzo with the Georgia Coastal Equity and Resilience (CEAR) Hub (Clarke et al. 2022; Di Lorenzo et al. 2022), we anticipate that the sensor locations will target critical infrastructure identified by local stakeholders (e.g., **Figure 1**). We will collaborate with the CEAR Hub to replicate the community co-design processes (e.g., **Map Room**, **panel below**, Loukissas et al. 2018; 2019) and expand the water-level sensor network to include sensors relevant for population health and well-being in the pilot communities (e.g., temperature, air quality). These hyper-local sensor networks provide a critical stream of county-scale data that will inform the community-driven resilience metrics (**TASK 6**). The data streams generated in this task will be integrated in NERACOOS (deliverable **D1, Figure 3**) as a permanent infrastructure serving the NE coast and in the CHAMP and community dashboards (**D4, Figure 3**) (see timeline **Table 3, section 5**). Equally important, the process of co-designing and deploying these networks in a collaborative research framework will connect local, regional, state, and academic stakeholders, many of whom are local residents, who had previously had little social interaction. Such collaborations form integrated social networks that increase the socio-ecological resilience of communities (Paolisso et al. 2019). Social networks protect against disaster impacts and promote recovery when disasters occur because they facilitate the exchange of information and monetary or material assistance (Folke, 2006; Cutter et al. 2008;Aldrich and Meyer 2015; Cutter, 2016). Many studies

(e.g., Townshend et al. 2015; Patel and Gleason 2018; Fan et al. 2020) document how communities with strong social networks were better able to cope with the disaster and recover more quickly.

TASK 3. Community-Driven Resilience Metrics (Leads: Fussell, Moretti)

Climate change impacts human health and social well-being through multiple mechanisms including discrete disasters, such as hurricanes, and gradually worsening environmental stressors, such as air pollution, tidal flooding, and rising summer temperatures (Patz et al. 2005). Environmental stressors negatively influence health directly (e.g., trauma, drownings, heat stroke) and indirectly (e.g., exacerbating chronic illnesses, mental health, changing infectious disease patterns) with both short and long-term consequences (Lane et al. 2013, Baker et al. 2022). These impacts have been quantified following climate disasters (Romanello et al.; Parks, et al. 2022) but we know of no community level studies that add health metrics to downscaled climate models to project future health impacts at the community level.

Concept	Source	Datasets
Health	**Robert Wood Johnson**	County Health Rankings
	Centers for Disease Control	Interactive Database System
Healthcare utilization	**Centers for Disease Control**	National Ambulatory Medical Care Survey, National Hospital Ambulatory Medical Care Survey, Multiple Cause of Death Mortality Data.
	American College of Emerg. Phys.	Clinical Emergency Data Registry
	Healthcare Cost and Utilization Project	Nationwide Emergency Department Sample, State Inpatient Databases, State Emergency Department Databases
Residential Habitability and Demographics	**U.S. Geological Survey**	National Land Cover Database
	U.S. Census Bureau	Decennial Censuses, American Community Survey, County Migration Flows Database
	Centers for Disease Control	Social Vulnerability Index, Environmental Justice Index
Labor markets	**U.S. Census Bureau**	American Community Survey, Current Population Survey
	NOAA	Commercial Fisheries Statistics
Weather	**National Weather Service**	North American Mesoscale Forecast System, Climate Forecast System Reanalysis (CFSR)
	ECMWF	ECMWF Reanalysis v5 (ERA5), Ocean ReAnalysis System 5 (OCEAN5)
Climate Projections	**World Climate Research Program**	Coupled Model Intercomparison Project v6 (CMIP6) models, Coordinated Regional Climate Downscaling Experiment (CORDEX)
Coastal Modeling	**Rutgers U.**	DOPPIO 7km reanalysis, 2007-2020
	North Carolina State U.	Coupled Northwest Atlantic Prediction System (CNAPS2) reanalysis, 4km, 1993-2022
	URI/Brown	Ocean State Ocean Model (OSOM), 50m, 2017-2018
	NERACOOS/UMass-D	Northeast Coastal Ocean Forecast System (NECOFS)

Table 1. Resilience metric concepts and datasets

Community characteristics – such as demography, poverty, housing, labor markets, urban infrastructure, health, and healthcare access – interact with climate change effects on human health and place habitability. As change in socio-ecological systems erode local livelihoods and residential habitability, communities may reach a social tipping point, causing a non-linear increase in out-migration (McLeman 2018). Such tipping points are not easily identified *ex ante*, but depend on community members' perceptions of the conditions necessary to adapt in place. Identifying habitability concepts is an active area of research for the study of climate-related migration, particularly in response to sea level rise (Hauer et al. 2020; McMichael, et al. 2020; Detges, Wright, and Bernstein 2022) and one that has proved important in developing and implementing resettlement processes (National Academies of Science 2023).

Understanding and managing the unique needs and challenges faced by these communities is important for decision-making by policymakers as they develop climate adaptation and health resilience strategies and solutions for coastal communities. Building on the activities of the Community Knowledge Collective (**TASK 1**), we will identify resilience metrics relevant to each pilot community. Core themes to be explored under this TASK include population health, healthcare utilization, residential habitability and migration, socio-demographics, and labor market vulnerabilities (**Table 1**). Metrics will be operationalized using existing data sources. In addition, new data may be collected directly from communities through workshops and site visits. As an example, if community stakeholders identify the burden on the healthcare system from a hurricane as a leading concern, we will measure hospitalizations and emergency department volume as a metric for this concept. The longitudinal data identified in **Table 1** and other potential sources will allow us to model change in each metric following a past event, which can be used to predict impacts of future events.

The links between climate and resilience metrics will be explored using data-driven methods (**TASK 6**) leveraging historical weather and climate data, novel data streams from hyper-local sensors and the coastal observing system (**TASK 2**). Quantifications will be mapped with the NE-CHAMP system (**TASK 5**) and incorporated into downscaled climate projection models (**TASK 7**) over both near-term (up to 15 years) and long-term time scale storylines (**TASK 4**). Health and residential habitability and mobility projections will then be shared back with the community in an iterative synthesis process (**WS3** & **WS4**) to further refine resilience metrics (deliverable **D2**). In addition, a subset of identified metrics will be applied across all pilot sites to identify commonalities and identify robust resilience metrics scalable across New England coastal communities. A timeline of this TASKs in relation to others is presented in **Table 3 (section 5)**.

TASK 4. Community Storylines & Scenarios of Climate Change (Leads: Becker, Fairbanks)

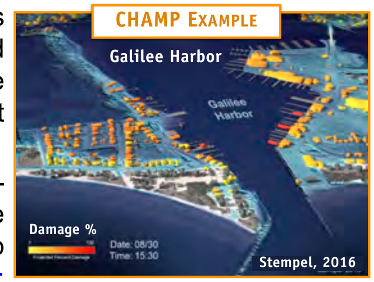
Effective policy development around post-disaster rebuilding or managed retreat (Siders, 2019) requires a coupled human and environmental understanding of the hazard-migration relationship anchored in the social sciences (Binder et al. 2015). Through the community workshops, we will engage stakeholders in exercises to characterize and prioritize future climate scenarios that connect climate drivers with consequences and a range of outcomes (Chen et al., 2021). Climate scientists use Representative Concentration Pathway scenarios and Shared Socioeconomic Pathways (RCPs and SSPs) to illustrate possible futures and guide physical modeling parameters, but here we plan to co-design local scenarios including key decision points that reflect the values and concerns of each community. Selected scenarios will drive modeling, projection, downscaling and analysis of key impact metrics (e.g., time horizons, scale/resolution requirements, physical and socioeconomic impacts, frequency and severity of events, and other modeling outlined in **TASKs 5-7**). Selected scenario *storylines* (IPCC, 2022; Shepherd et al., 2018) will guide discussions, lesson plans, and narratives throughout the project. Using ESRI Storymaps interface we will visualize and deepen understanding of moments in time during the storyline. NE-CHAMP (Becker et al, 2021) will be leveraged to enhance storymaps, as it is also based on the ESRI platform, which is widely used (by partners, e.g., NERACOOS, and local organizations, e.g., Narragansett Bay Estuary Program) and can be expanded upon to include new metrics and visualization. Along with each storymap in the web narrative, NE-CHAMP will display neighboring outcomes and other variables to facilitate risk awareness, decision-making, agency and ownership of the co-developed tools, and the boundaries of plausibility (Shepherd et al., 2018).

Scenarios will also include the potential for population loss through out-migration, which is likely inevitable in communities that are highly exposed to climate-related hazards (GAO 2020). Using county-level migration flow data for the U.S., Fussell and colleagues show that migration from New Orleans after Hurricane Katrina largely follow migration patterns existing before the disaster (Fussell et al., 2014, 2022; Curtis et al. 2015, 2020; DeWaard et al. 2016). The workshops (**WS2**) will gather information from residents about their experiences with population loss through migration and their expectations for place habitability in the near and more distant future given past experiences with coastal hazards and expectations for climate change. We will also share data with community members on their community's migration system, including all the places they are tied to through in- and out-migration flows and the size of those flows. This information includes anecdotal information on friends, relatives, and acquaintances who have migrated in or out. An update of the storylines will be conducted in the context of the evaluation of future climate scenarios through iterative workshops (**WS3, WS4**), which will allow us to develop a synthesis of current and anticipate future adaptation storylines (deliverable **D5**). The team already has experience co-developing scenario evaluation and planning workshops with communities. GMRI has organized 4 hour workshops to create climate scenarios planning for a specific threshold of sea level rise in 2050.

TASK 5. Modeling Coastal Impacts for Analysis & Prediction (Leads: Pringle, Becker)

Sea level and water conditions at the land-sea interface, and their impacts on infrastructure and people, are influenced by ocean forcing at larger spatial and slower temporal scales. Models will translate from larger scales (from present-day reanalysis and future climate model projections) to the infrastructure and human scale of interest here. The Coastal Hazards Analysis, Modeling, and Prediction System (CHAMP) is an existing, proven high-resolution, real-time hazard impact forecasting and resilience planning tool initially developed for emergency management (Becker et al 2021). It has been developed with funding from the Department of Homeland Security Center of Excellence in Coastal Resilience that is currently being operationalized for state emergency management and also being piloted as part of NOAA's Environmental Response Management Application (ERMA). CHAMP combines bottom-up, stakeholder-derived qualitative data with high-resolution storm surge and sea level rise models, at present the ADvanced CIRCulation model, to analyze non-linear combined impacts of storm surge and sea level rise

(Stempel et al 2018) (see example **panel on the side**). CHAMP utilizes "consequence thresholds" (CTs), defined as the measurable threshold (e.g., wind speed, surge depth, wave height) for a qualitative consequence (Witkop et al 2019). This project will expand CHAMP to cover the NE coast with two important enhancements (part of deliverable **D4**):



Visualizing projected flood damage on critical infrastructure

<u>(1) Improved Mapping of Climate Hazards over NE coastline.</u> Coastal sea-level results from global and regional dynamics at the boundary of the continental shelf. The shelf partially isolates the coast from the deep ocean, modifying the oceanic sea-level signal (Chapman & Brink, 1987; Little et al., 2019; Wise et al., 2018]. Tides; waves; glacier and ice sheet change; gravity, rotation, and earth deformation; land water storage; and vertical land motion are not explicitly found in climate models, and they must be added to open ocean conditions to arrive at coastal sea level, extreme sea level, and inundation metrics (Fox-Kemper et al. 2021). Simultaneously, forcing on the continental shelf from local and remote winds (Battisti & Hickey, 1984), atmospheric pressure (Piecuch & Ponte, 2015), remote waves (Hemer et al., 2013), and remote (Pringle, 2018) and local (Durand et al., 2019) river inflows affect coastal sea level, in a manner sensitive to model resolution (Hampson & Pringle, 2022; Little et al., 2019). At present, CHAMP uses a high-resolution unstructured-grid sea level model (Ullman et al. 2019) throughout New England based on specified offshore conditions, winds, and precipitation derived from coastal and offshore models. A high resolution, data assimilating regional model configured for the Mid-Atlantic Bight and Gulf of Maine by the Rutgers Ocean Modeling Group (DOPPIO) has been run from 2007 to the present, and will be run to at least 2026 (López et al., 2020; Wilkin et al., 2022). This freely-available modeling output and forcing will be leveraged to consider other hazard metrics for inclusion in CHAMP, such as sea surface temperature and atmospheric conditions, as needed to fulfill the community-developed goals. DOPPIO has shown skill when assimilating altimetry on the shelf and when running without data assimilation (Wilkin et al., 2022), so it can be leveraged as a dynamical downscaling method for future climate conditions as well. A similar coastal model built by our team including half of our pilot sites (OSOM: Sane et al., 2022) has been used for dynamical downscaling of a high-resolution climate model (Benoit, 2022). Other coastal models, such as NECOFS and CNAPS2, will be compared for cross-evaluation. All of these models or an ensemble estimate can be incorporated seamlessly into the CHAMP framework to address the co-designed scenarios and storylines. A list of data sources are in **Table 1**.

<u>(2) Mapping and Analysis of Health and Socioeconomic Resilience Metrics.</u> Building on the work of **TASKs 3,4** NE-CHAMP will be expanded to map, analyze, and compare the covariability between climate hazards and the community-driven metrics from **TASK 3**. To this end, we will develop and integrate in NE-CHAMP data-driven models to examine and map the links between physical variables and the social, economic, and health metrics – these links are described in the next **TASK 6**. Finally, NE-CHAMP will also provide the mapping interface to organize storylines/storymaps of **TASK 4** (deliverable **D5**).

<u>TASK 6. Data-driven Models to link Climate, Health, and Migration (Leads: Bergen, Fox-Kemper)</u>

While the specific resilience metrics to be co-developed with community input cannot be fully anticipated, the makeup of our team involves experts in public health, medicine, migration, fisheries, coastal infrastructure and systems, and the collection of qualitative data. Measurement error is present in all databases (Cheng et al. 2012, Cambridge and Cina, 2010; DeWaard et al. 2020), so a probabilistic approach incorporating team expertise is critical in finding robust climate-society relationships. Along with errors, we will investigate sources of bias and ensure “algorithmic fairness” in our datasets (Mhasawade et al., 2021). In our pilot communities, and across the US, there are datasets coincident with weather and climate records that inform these types of metrics (**Table 1**), but unlike physical variables, there is not a generic, mechanistic approach to modeling these diverse climate-driven impact metrics into the future. For this reason, addressing these metrics requires statistical or data-driven covariability approaches.

This task aims to expand the NE-CHAMP capabilities (see **TASK 5**) by developing data-driven models (e.g., statistical and machine learning) of the socioeconomic and health effects of climate change on the pilot communities as well as other coastal populations across the U.S. by examining the co-occurrences of hazards, exposures, and vulnerabilities. To do so, we will use Bayesian inference to combine data from various sources (**Table 1**), including mortality data, extreme weather reanalysis, and census data on income, employment, education, age, and other demographic variables. The Bayesian framework will establish the added value of each dataset in estimating the effects of climate change at a granular level, requiring analysis at the zip-code or county-level resolution within multidecadal datasets. The project aims to understand the interactions between climate hazards from model projections, community- and individual-level exposures and vulnerabilities, and their effects on socioeconomic and health outcomes. Data-driven models will inform health and infrastructure policy thereby contributing to adaptive capacity. Our models will improve on existing studies that tend to either emphasize regional impacts under recent extreme conditions (e.g., Limaye et al. 2019, Parks, et al. 2022, Santos-Burgoa et al., 2018) or national impacts under climate event attribution using projections (e.g., Clarke et al. 2021). In contrast, our study seeks to deliver regional impact attribution from climate projections by synthesizing data streams (requiring the three **TASKs 5-7)**. Our approach will deliver knowledge of community- and individual-level risk factors of extreme weather and flooding events downscaled to our coastal regions and populations, thereby informing community-level adaptation and disaster preparedness (Vaidyanathan et al., 2019).

Infrastructure adaptations, such as home improvements and better treatment of health precursors, can reduce exposure and vulnerability and therefore climate risk. Thus, the health impacts of climate change are multifactorial and depend upon qualitative data, future adaptations, and other data that will become evident in our community scenario development exercises. For instance, Gronlund (2014), Berberian et al. (2022), and Abualsaud et al. (2019) demonstrate the impact of socioeconomic disparities on heat-related mortality via a variety of risk factors such as air conditioner use (Bouchana et al. 2007), occupational exposure in farmworkers (El Khayat et al. 2022), and access to greenspace (Hsu et al. 2021). Our coastal populations are in cold regions, and despite global warming, many people are still exposed and vulnerable to cold temperatures: 101,292 deaths in the US were attributed to extreme cold in 2019 compared to 9,854 deaths attributed to extreme heat (Burkart et al. 2021). We will go beyond a few dynamical scenarios with linear statistical models at coarse resolution by augmentation with machine learning approaches such as neural networks and decision trees to provide additional skill & precision.

Migration away from climate-related hazards and eroding habitability is a distinct possibility in coastal communities (Hauer et al. 2020; McMichael, et al. 2020). Drought, rising temperatures, and sea level change alter the environment and affect livelihoods, such as fisheries and farms, and can alter pressure to migrate over time. Extreme and rapid onset events like tropical storms and hurricanes, heat waves, and floods from storm surge can drive migration by loss of residences, businesses, crops, livestock, and infrastructure. Increasingly frequent extreme events or trends that intensify or cross key thresholds may cause residents to move in anticipation of worsening habitability. Thus, projections of climate change-triggered migration require regionally-specific and accurate trends and extreme statistics, as well as an understanding of the vulnerability of critical infrastructure. Our project seeks to better understand and model these dependencies through the community meetings and resilience metrics and then visualize and make them actionable through storylines and NE-CHAMP storymaps produced during **TASKs 4 & 5.** The historical census data will be used to develop and evaluate migration connections.

The connections between hazards and health and migration are scale-dependent and based on geographic, political, and/or socially-defined boundaries, so consistent climate projection downscaling to our regions will also be required (see **TASK 7**). Our project seeks to better understand and model these dependencies. Thus, we will establish the hazards in **TASKs 2 & 5**, the metrics in **TASK 3**, relate them to risk relationships in **TASK 6**, and **TASK 7** will use weather and coastal data together with present-day and historical climate model simulations to downscale. Machine learning, statistical modeling, and downscaling designed to highlight unlikely extreme events are to be developed for **TASK 7** consistently with this **TASK 6** analyses of historical dataset covariabilities. By this multi-step approach, future climate projections can be connected to future risks on the scales and metrics important to our communities.

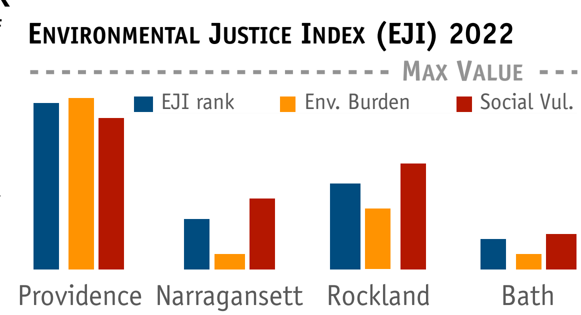
TASK 7. Downscaling Climate Projections & Model Scenarios (Leads: Fox-Kemper, Chini)

Raw climate model projections are only the beginning to understanding climate change and its impacts on the space and time scales that are meaningful to coastal populations. IPCC and USGCRP assessments of model projections do not reach this level of regional refinement. Regional assessments using dynamical downscaling systems such as coastal models and CORDEX experiments can highlight changing hazards (Doblas-Reyes et al. 2021; Ranasinghe et al. 2021) and extreme events (Seviratne et al. 2021) and their attribution to climate change (Clarke et al. 2021). High-resolution climate model forcing on the 25 km scale will be used to drive regional models to arrive at the 1km scale or finer in terms of coastal hazards and inundation, which will be included in the NE-CHAMP (**TASK 5**) system. However, direct regional dynamical downscaling is computationally expensive: it limits the timespan that can be directly simulated and does not allow us to downscale projections from large ensembles. Ensembles can measure uncertainties arising from natural variability (single-model ensembles) and model errors and biases (multi-model ensembles). This means that events that are unlikely, yet the most damaging climate extremes, may be missed. They are critical to include for health and migration impacts (**TASK 6**).

Regional data at high resolution from (1) the new sensor network, (2) high-resolution satellite datasets, and (3) a targeted set of dynamical downscaling simulations, will be used to train data-driven regionally-specific predictors for downscaling a set of climate models large-ensembles projections. The approaches used will be applicable to any region. The team has exploited *unsupervised pattern recognition* to identify climate and environmental hazards on sub-kilometer scales near two of our pilot regions (Benoit & Fox-Kemper, 2021). Cloud computing tools such as Google Earth Engine (Gorelick et al. 2017) and Pangeo will facilitate the availability of data and the training of data-driven systems. The group has proven these tools in comparing kilometer-scale data with centers around the world (Uchida et al. 2022) and in regionally-refinement and bias-reduction of datasets (e.g., Benoit & Fox-Kemper, 2021, Hall & Fox-Kemper 2021). High-resolution observational products, such as heat severity index maps (**Table 1**), can be used to categorize neighborhood-level variations in hazards, and machine learning can leverage such data to improve on climate projection resolution (Wang et al. 2022). For example, DOPPIO will train machine learning models of coastal sea-level as a function of the basin scale sea-level, the river forcing in the system, and the winds over the shelf region. These downscaling ML models will be tested with out-of-sample sea-level measurements from the new sensor network (**TASK 2**). If satisfactory, they will downscale atmospheric and oceanic climate models of future conditions to coastal sea-level variability. Similar new tools, such as the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) and the Google.org flood forecasts (Nevo et al. 2018, 2020) prove such approaches work even over a global or national scale. If skillful, these approaches will be integrated into NE-CHAMP.

Physics-informed emulators will combine the knowledge of climate scientists together with the data-processing power of machines to produce accurate prediction systems. Physics-informed machine learning helps to ensure physically-reasonable projections even in out-of-sample conditions and alleviates data sparsity (Ben-Haim et al. 2019). The team has recently developed physics-informed emulators (Hall & Fox-Kemper 2021, Nicklas et al. 2022) to understand CMIP6 metrics and their uncertainty across the ensemble. Co-Is Bergen and Fox-Kemper are supervising a student investigating if neural networks can improve on the efficiency and accuracy of the ice sheet and glacier emulators used in the IPCC sea level assessment (Fox-Kemper et al. 2021, Edwards et al. 2021). *A hybrid variational/statistical/data-driven approach* for predicting extreme events (Farazmand & Sapsis, 2019) including training acceleration by Large Deviations Theory (Bouchet et al. 2016), will also be developed and implemented. This blended approach combines a small amount of data characterizing location near the chaotic attractor with the equations of the dynamical system to identify unstable regions of phase space where extreme events are triggered. This novel approach has been successful in characterizing extreme events in idealized turbulent systems, but not yet in applications. It facilitates short-term prediction and efficient quantification of the tails of the probability distribution. Machine learning (McGovern et al. 2017) and variational approaches can also be used to find extreme event precursors and predict near-term events.

The downscaling information generated in this TASK will be linked in the NE-CHAMP data visualization layers to support the climate scenario evaluation (**TASK 4** and **WS**), and assembled as a curated database of downscaled ensemble climate projections with uncertainties and probability (deliverable **D3**).



3.1 Research impact in affected populations

The four pilot communities are ports vulnerable to coastal climate change, but their differences link broadly to other NE sites. The Environmental Justice Index (EJI; see **panel on the right**) was calculated for each port. The bars indicate the percentage of US Census tracts with lower scores, the EJI combines environmental burden (air, ground, water contamination) and social vulnerability (demographic, socioeconomic, housing, and health metrics).

The Port of Providence at the head of Narragansett Bay and confluence of three rivers is one of two deepwater ports in NE and the primary energy port for RI, including wind farm construction capacity. It lacks a port authority, being governed only by local and state laws. This project would be the sole long-term planning for the port as a whole. Residential areas near the port rank high in EJI due to port- and interstate-related pollution and social vulnerability (low-income, number of children).

The Port of Galilee is Rhode Island's largest commercial fishing port located in Narragansett, managed by RIDEM. It mainly serves the commercial fishing industry (Becker et al. 2010). Activity at the port adds $420 million to the RI economy and over 4300 jobs. A low environmental burden attracts higher income residents and retirees to the surrounding community. 92% of residents are non-Hispanic whites, and compared to the other communities, residents have the highest levels of education and income.

Rockland is a mixed-use working waterfront with commercial fishing, a US Coast Guard Station, shipbuilding, tourism, and a state ferry dock connecting to Vinalhaven, the second-largest lobster landing port in ME. Rockland is a Justice40 community: it is underserved, under-resourced, and vulnerable to climate change, pollution, and environmental hazards. Toxic release inventory sites, mining, highways, and railroads account for the high environmental burden. Rockland has a rural character with high levels of poverty, unemployment, and housing cost burden, and many residents lack health insurance.

Bath, a small city of 8,780, is home to a naval shipyard, Bath Iron Works (BIW), one of the largest employers in ME with 6,700 employees. 95% of residents identify as non-Hispanic white, and 95% have graduated from high school. Social vulnerability stems from residents of retirement age and in mobile homes. Economic vulnerability due to coastal flooding is high, as BIW and city services are in a low-lying area near a tidal river.

The research impacts of the proposed project, 3CRS, build the human capacity of the pilot communities by providing community participants - local decision makers, waterfront stakeholders, residents, and youth - with collective understanding of concerns, consequences, and recommendations for holistically building climate resilience. The expertise developed by 3CRS to advance climate planning will constitute a shared resource for waterfront working rural communities and unmanaged ports.

3.2 Interjurisdictional Collaborations and Partnerships

Synergies across Institutions and Team Expertise. The 3CRS is a transdisciplinary project spanning the social, health, and natural sciences, and is rooted in community-driven collaborative research and training. To this end, the project brings together a necessary set of complementary expertise from six institutions across three EPSCoR states of RI, NH, and ME (summarized in **Figure 4**). Specifically, **Brown** will serve as lead and contribute to the social, health, computer, and climate sciences elements of this project; **URI** brings a long-standing working relationship with the RI pilot communities and the CHAMP system development; **RIC** has established experience in workforce development in RI; **GMRI** brings long-standing working relations with the ME pilot communities and is experienced in developing training modules and workforce development in ME; **NERACOOS** is responsible for the sensor data and is a NOAA funded infrastructure that supports the Integrated Ocean Observing System along the NE coast, and finally, **UNH** brings experience with coastal modeling and physical oceanography of the NE region. The individual expertise of the team is shown in **Figure 4**.

INSTITUTIONS COMPLEMENTARY STRENGTHS & TEAM EXPERTISE

Social, Health, Computer, & Climate Sciences
Brown University RI
Emanuele Di Lorenzo (PI) (Climate Dynamics & Modeling)
Baylor Fox-Kemper (Climate Modeling, Machine Learning)
Karianne Bergen (Computer Sciences, Machine Learning)
Elizabeth Fussel (Social Sciences, Population Dynamics)
Rachel Baker (Public Health, Disease Modeling)
Luke Fairbanks (Human Geography, Qualitative Modeling)
Leslie Acton (Social Sciences, Ocean Governance)
Katelyn Moretti (Emergency Medicine, Climate & Health)

Rhode Island Communities Links & CHAMP
University of Rhode Island (URI) RI
Austin Becker (CoPI) (Social Sciences, CHAMP)
Pam Rubinoff (Community Liaison RI, Resilience Specialist)
JP Walsh (Director, Coastal Resource Center)

Maine Communities Links & Workforce Development
Gulf of Maine Research Institute (GMRI) ME
Dave Reidmiller (CoPI) (Climate Services & Policy)
Gayle Bowness (Community Liaison ME, WD Co-Lead)
Kathy Mills (Fishing Communities Adaptation & Resilience)

Sensors Networks
Northeastern Regional Association of Coastal Ocean Observing System (NERACOOS) NH
Tom Shyka (Data Management and Observing Systems)

Coastal Oceanography & Modeling
University of New Hampshire (UNH) NH
James Pringle (CoPI) (Coastal Modeling, Physical Ocean.)
Gregory Chini (Statistical & Coastal Modeling)

Rhode Island Workforce Development
Rhode Island College (RIC) RI
Anabela Maia (CoPI) (Workforce Development Co-Lead)
Lisa Bain (Director, RI STEAM Center)

FIGURE 4

Collaborative Structures & Mechanisms. To advance 3CRS and its community-driven research, we have identified the following collaborative structures. The community partners engaged in these structures will be supported through honorarium, stipends and/or community space rental fees.

1. Community Partners & Researchers Team (CPRT). Using our existing community connections, we will assemble the CPRT by bringing together members of the research team (i.e., **Rubinoff**, **Bowness**, Reidmiller, Fussell, Acton, Fairbanks, Moretti, Becker, Walsh, Maia) with selected members of the pilot communities. These include representatives from the people's port authority organizations of Providence and Galilee, sustainability coordinators from mayors' offices, members of community organizations and local sustainability boards, and representatives of local industries such as fishing and shipbuilding (see letters of commitment). The community representatives from each locality will provide expert knowledge on local vulnerabilities, specifically, how the people, systems, and resources in their community are or will be impacted by climate-related environmental changes.

2. Regional Advisory Board (RAB). The board will be composed of representatives from the pilot communities and other communities throughout the New England coast, including Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut. The RAB will support the 3CRS planning and decision-making processes in the pilot communities and become part of the social infrastructure for transmitting lessons to constituencies throughout New England. The RAB will be part of an ongoing effort led by mayors across the US to create a national Community of Practice (CoP) for coastal resilience that provides access to resources for underserved coastal communities impacted by climate change.

3. Community Workshops (WS). We will host five **WS1-5** rounds over the course of the project (see timeline **Table 3**) as one of the mechanisms to advance the community-driven research (see references to the WS in the TASKs descriptions) and training activities. A summary description of the scope of each WS has been already provided. Each workshop has 4 sub-workshops, 1 per pilot community.

4. *Cross-disciplinary Teams*. In addition to the CPRT, we will also establish 4 additional science teams that cross disciplinary expertise (co-leads are in **bold**): **Workforce Development Team (WDT)** (**Maia**, **Bowness**, Reidmiller, Bain, Di Lorenzo) will coordinate TASKs 8-11; **Data & Impact Metrics Team (DIT)** (**Di Lorenzo**, **Shyka**, Fussell, Moretti, Mills, Becker, Baker, Fox-Kemper, Fairbanks Chini,) will coordinate TASKs 2,3,5; **Modeling and Projections Team (MPT)** (**Fox-Kemper**, **Pringle**, Chini, Walsh, Di Lorenzo, Mills) will coordinate TASKs 5,7; and the **Machine Learning Team (MLT)** (**Bergen**, **Fox-Kemper**, Pringle, Chini, Fussell, Moretti, Baker) will coordinate TASK 7.

National and International Collaborations. The RAB will be integrated into a nationwide effort led by the *Center for Sea Rise Solutions* (led by Mayor of Sausalito, CA) (see letters) in collaboration with mayors across the US to empower local officials to take adaptation actions against the threat of sea-level rise. As part of this effort, the NE RAB will be one of several across the US that will be connected to a National Community of Practice for Coastal Resilience. Furthermore, the 3CRS framework will be shared as a US pilot contribution to the coastal resilience efforts of the *Global Ecosystem for Ocean Solutions (GEOS)* UN Ocean Decade Program under the SEAT'IES project and in coordination with the UN Decade Center for Coastal Resilience. The GEOS program is hosted by Ocean Visions, a non-profit founded by PI Di Lorenzo in 2019. *Information about these partners is provided in the list of collaborators.*

3.3 Sustainability of the Team

Mobilizing New Resources to Support Infrastructure beyond the Project. There are several pathways to secure resources to support and expand the project deliverables (**Figure 3, D1-D8**) in the future (e.g., congressional support, new federal and state grants). Here we provide some concrete examples of how previous seed funded work by members of our science team has led to new resources that ensured the long-term sustainability of infrastructure elements that are similar to the one developed by 3CRS. **(1) The Georgia Smart Sea-Level Sensor (SSLS) Network** initiated in 2018 by PI Di Lorenzo and others at Georgia Tech developed a community-driven water-level sensor network similar to the one proposed in **TASK 2**. By bringing together and engaging Georgia communities in the development of the network, this project raised sufficient state awareness of sea level rise. This led the two state senators to secure a $5M earmark in 2022 to establish *The Georgia Coastal Equity and Resilience Hub* that extends this effort along the entire GA coast with direct support to several community-led social justice organizations. Also in 2021, emergency managers in the SSLS team successfully secured a $5M state grant to establish a Coastal Resilience Center in Camden County. **(2) EPSCOR Rhode Island Consortium for Coastal Ecology Assessment, Innovation, and Modeling (RI C-AIM) Project** that aimed at building capacity for understanding the impacts of climate on coastal ecosystems unlocked an additional $48M of external funding to expand its reach in the state of RI. **(3) The Rhode Island CHAMP system**, which will be expanded for the NE coast, is currently being operationalized within RI's Emergency Management Agency and is used for risk assessment, planning, and training at RIDEM. It was also utilized to conduct a Military Installation Resilience Review for Navy Station Newport (RI) in collaboration with three municipalities and other key stakeholders.

Towards a 3CRS New England Hub. RI, NH, and ME have numerous academic, private, NGOs, and government agencies involved in resilience efforts, yet all have limited capacity to understand climate change hazards, identify adaptation solutions and develop paths for progress. While there are many differences in geography and socioeconomic factors, the 3CRS framework will serve as a foundation for developing a NE hub for sharing, collaborating, and coordinating efforts and new funded projects on coastal climate and resilience. Already, this project brings together multiple institutions with complementary expertise across the NE EPSCoR jurisdiction that have never collaborated collectively. The human networks and partnerships developed under these projects, including the RAB, the science teams, and the community relationships, will build interjurisdictional trust across the intuitions and enable growth in coastal climate research. The training curriculum and the new grants in this area will lead to the hiring of new faculty and institutional investments.

3.4 Workforce Development (Leads: Maia, Bowness) **(Training TASKs 8-11)**

We aim to develop multiple workforce development activities derived from the research components of this proposal with the goal of enhancing the resilience of coastal communities in New England. These will be geared towards grades 6-12, college and graduate school students, as well as local community members and decision makers through five main initiatives: 1) attract, recruit, mentor and retain early career faculty; 2) curriculum development for grades 6-12 and professional development for educators for wider dissemination and sustainability (**TASK 8**); 3) train undergraduates, graduate and post-doctoral fellows by offering technical workshops for scientists (**TASK 9**); 4) offer informational workshops on resilience to coastal flooding geared towards our community partners as highlighted in **TASK 1** of the proposal (**TASK 10**); 5) boot camps on climate planning and tools for local decision makers (**TASK 11**).

Attract, recruit, mentor and retain early career faculty (all academic partners). This proposal aims to foster collaboration among early career faculty (5 women: Baker, Moretti, Bergen, Acton, Lummis, 1 male: Fairbanks, 1 person with disability: Acton) and offer opportunities to expand their research in order to increase retention of high-quality faculty in Maine, New Hampshire and Rhode Island. We anticipate that this project will also attract new faculty and staff to the institutions involved. Senior faculty members will function as mentors to increase high impact practices by early career faculty. The interdisciplinary nature of this project will expand the faculty's research spheres and training on community and stakeholder engagement.

TASK 8. 6-12 Education modules (GMRI, RIC, RI STEAM). In collaboration with coastal high school teachers, GMRI has a sea level rise curriculum (currently in draft, release date planned for Spring 2023) for middle and high school students giving them knowledge, skills, and confidence to engage their communities around sea level rise. The young will live with, adapt to, mitigate, and plan for climate change as they enter adulthood, so a multigenerational engagement strategy strengthens value for communities and increases urgency around finding adaptive solutions to reduce vulnerability. The core curriculum guides students through different questions (see **panel below**):

What is sea level rise?	*How will sea level rise impact my community?*	*How can I help my community prepare for sea level rise?*
Students explore the science, data, causes, and impacts of sea level rise on a global scale and examine local projection data.	Students interview local community members about how their community values the coast and observed change over time. Students then contribute data about local high water and flood impacts through a community science project.	Students roleplay as community planners and stakeholders to appreciate the complexities of sea level rise planning. They then design and deliver a communications campaign to build community understanding.

The curriculum is flexible to allow teachers to suit their and their students' needs. The culminating communications campaign is driven by student choice and will demonstrate not just their understanding of sea level rise, but communicating climate change, as modeled with best practices throughout the curriculum. The NE-CHAMP dashboard and storylines (**D4**, **D5**) and other project outputs will be integrated to create accessible resources and curriculum for heightened engagement.

We plan to leverage activities and platforms developed with support from NSF EPSCoR Track-2 RII RI C-AIM which include data visualization tools in an educational platform entitled SimpleChartsRI (Spaulding et al. 2021) and to include hands on activities using a sandbox model of the coastal areas superimposed with a projected coastline map of projected water levels (Aljabal et al. 2019). This activity helps students visualize the implications of erosion and loss of buffer areas such as marshes providing ecological services. These activities will be taken to the schools and students will be transported to field sites where they can observe these processes in real time. To reduce barriers to access, we will provide logistical support and planning in areas where schools have reported to be bottlenecks. In order to increase buy-in from school communities and to increase the participation of affected communities, events hosted at the 3CRS planned workshops (see **Table 3**) will also be made broadly available to other teachers in the NE area so that these activities can be implemented in their teaching plans. Stipends to teachers attending workshops will be provided. This curriculum will be implemented in both Maine and Rhode Island at schools that enroll students from the pilot communities: in ME: Bath Middle School, Morse High School, John W. Rogers Middle School and Rockland High School; in RI: Mount Pleasant High School, East Providence High School and Narragansett High School.

TASK 9. Train undergraduate, graduate and postdoctoral fellows (all partners). This project will provide training opportunities in scientific domains, science education and community engagement to undergraduate, graduate students and postdoctoral scientists at multiple institutions including Rhode Island College (RIC), a primarily undergraduate institution (PUI) and hispanic serving institution (HSI). At least 8 undergraduate students during the academic year and 12 students during the summer from RIC, will participate in each year of this project. Undergraduates will also be recruited for a summer at GMRI's NSF Research Experience for Undergraduates, NOAA's Inclusive Fisheries internship programs, and Colby College's Buck Lab for Climate and Environment summer internships, all focusing on diverse and underrepresented college students. Students will benefit from direct mentors and the 3CRS community at large. Masters (2 at RIC) and doctoral (1 at Brown and 1 at URI) graduate students and five post-doctoral fellows (2 at Brown, 1 at UNH, 1 at URI, 1 at GMRI) will be directly supported by this project. All trainees will be invited to scientific and community workshops focusing on increasing resilience to coastal climate change and weekly career mentoring meetings (see **Managment Plan** and **Postdoc Mentoring Plan**).

TASK 10. Informational Workshops on Coastal Flooding and Community Resilience (GMRI, RIC, RI STEAM). While building the capacity for workplace use of science-based information is essential, so is equipping people with the environmental literacy necessary to make informed resilience decisions in their everyday lives. When community members become engaged in resilience and make informed decisions, they reinforce the efforts of resilience practitioners and local or state officials. To this end, we will offer workshops in the four participating communities to inform and engage community members in coastal resilience planning efforts, which will run alongside the planned workshops in the different communities for gathering of community data, metrics, and narrative (**TASK 1-3**), but will be open to the entire community. As one of the primary goals of this TASK we will develop on-demand modules so that these workshops can reach a wider audience in the future **(D8)**.

The first workshops (**WS1, WS2**) will provide general information on localized climate impacts to build common knowledge and language. We will create space to recognize and honor the value of local knowledge allowing for community members to share how they have seen their community and coastline change over time. Facilitators will surface community values from diverse stakeholders, identify what community members find important about their place today and what they hope for the future. These values and identifications will inform the NE-CHAMP system (**D4**) supplemented with model information (**TASKS 5-7**) and will be incorporated into climate storylines (**TASK 4, D5**) and will be and community science according to best practices (Charles et al 2020). GMRI has been developing and leading community science projects since 2005 by working with community leaders and researchers to co-develop questions and data collection protocols for community engagement in science and data for decision-making needs.

Coastal towns face two critical obstacles that these activities plan to address: 1) difficulty in obtaining or accessing specific detailed data necessary to assess the relative vulnerability of municipal assets and coastal businesses; 2) low rates of engagement and understanding on the part of taxpayers and residents. The program that GMRI has designed and that this proposal plans to implement across NE provides guidance on how to contribute observations that help pinpoint high-risk flooding areas in coastal communities throughout the Gulf of Maine, as has the RI-CHAMP system in RI. Community members identify the weather and water level conditions during flooding events, and describe how the flood impacts their community. Collectively, these data inform decisions that support the prioritization of community resilience strategies. GMRI, RIC and the RI STEAM Center will expand tools for (see **panels below**)

Collect data that reveals the weather and sea conditions associated with localized coastal flooding	**Inform community actions** by methodically gathering residents' opinions on relative site values and impact concerns	**Raise community awareness** among residents about local flooding impacts and preventive measures such as adaptation and preparedness actions	**Create a region-wide protocol and network** for sharing flood impacts to ensure communities better understand their unique risks and can identify priorities for building resilience

We will also leverage existing capabilities such as community monitoring of flooding with MyCoast.org/RI where volunteers take pictures of storm damage and extreme tides tied to weather and tidal data.

The next round of workshops (**WS3, WS4**) - Planning Forward - will engage community members in the storylines **(D5)** developed under **TASK 4**, creating an opportunity for safe and open dialogue for community members to explore what climate scenarios mean for their community and for them to share with facilitators and local decision-makers priority areas and ideas and strategies for how they could collectively build community resilience. This will be modeled on a workshop designed by GMRI in collaboration with an advisory team consisting of federal, state, and regional experts as well as representative community stakeholders. Planning Forward aims to develop the internal capacity of communities through building knowledge, skills, and relationships needed to develop and implement effective climate action plans. Participants surface and use community values to guide conversation as they confront the difficult reality of our changing climate and consider possible futures through new perspectives. By providing a safe and open space to practice the difficult, real-life conversations about the consequences of climate impacts, such as sea level rise, and by modeling a problem-solving process we can empower the participants to take their knowledge and transform it into practice. The learning experience is rooted in NE-specific challenges and strategies that ground participants in a discussion that feels strongly relevant to the places they call home. Conversations around values and identity help empower participants to confront a difficult reality.

These activities will be closely integrated with other grant deliverables, including the generation of dashboards and storylines (**TASK 4, D4, D5**) which are ideal for conveying complex data. We will integrate the NE-CHAMP (**TASK 5, D4**) in the workshops and a responsive workshop design to integrate research progress and findings from other proposal tasks. On-demand modules (**D8**) will ensure that updated content is available past the sunsetting of the grant.

TASK 11. Boot camp on climate planning resources and tools for Local Decision Makers (GMRI, RIC, RI STEAM). With the goal of increasing coastal resilience training of Local Decision Makers, fast paced short workshops - boot camps - with an emphasis on the application of tools will be launched. The boot camp will convene new Mayors and local decision makers with existing officials experienced in the fundamentals of coastal resilience to accelerate the learning curve. It will train participants on how to deploy the solutions roadmap, and offer a range of technical and capacity building educational opportunities. We will model these boot camps after similar initiatives in other jurisdictions such as the *Center for Sea Rise Solutions*. These workshops will connect participants with relevant tools, resources, processes, and professionals through interactive presentations in a conference-like setting. On-demand modules **(D8)** will also be available to guarantee sustainability of these initiatives.

Evaluation and Sustainability. Surveys and education evaluations will be deployed after all the activities to students and educators to assess the effectiveness of the lessons in improving scientific competence, to engage and inspire students in STEAM, and to meet New England data literacy standards. Assessment outcomes will be reviewed by education teams in Maine and RI to improve the on-demand modules **(D8)**, and integrated in the 3CRS evaluation and assessment plan (next section).

Goal	Activities	Milestones	Timing
Build expert capacity and networks	· 6-12 Education Modules · PhD & Postdocs · Community Resilience Training modules · Local Decisions Makers Bootcamps	· Events conducted · Pre-post surveys, reporting, improvement · Student-Mentor pairings · 5 women ECF	Per occurrence Annually
Co-generation of knowledge and data streams	· Establish and expand research and engagement framework · Establish community knowledge collection · Develop multi-variate hyper-local sensors · Develop community-driven resilience metrics · Identify scenarios of climate change	· Proposals submitted · Manuscripts published · Presentations at conferences · Collaborations · Program evaluation, reporting, improvement	Semi-annually
Comparative analysis, modeling and pediction	· Develop curated database of downscaled ensembles · Hazards and resilience impacts mapped · Develop new statistical and ML methods of modeling · Utilize impact modeling for analysis and prediction · Downscale climate projections and model scenarios	· Database developed/updated · Maps developed with hazards and resilience impacts · Proposals submitted · Manuscripts published & conference presentations · Collaborations	Semi-annually
Expand Capacity & Tools for Resilience Planning	· Integration of coastal ocean observing systems · Synthesize community knowledge · Establish/synthesize scenarios of change	· Adaptation storylines documented · Create community dashboards/information systems · Evaluate methods of sharing information with community	Annually

Table 2. Evaluation and Assessment Plan

4. Evaluation and Assessment Plan (Lead: Kimberly)

Strategic assessment will be established externally for all the complementary and integrated activities between the institutions (summary provided in **Table 2**). The purpose of the evaluation is to answer the question, *Are the proposed EPSCoR activities successful at developing a workforce in RI, NH, and Maine dedicated to fostering equitable coastal solution strategies for climate resilience and health?*. Judy Kimberly, PhD will support the external evaluation of the workforce development components of this EPSCoR FEC proposal. Dr. Kimberly has over 20 years experience conducting evaluations of programs and projects including many NIH T32, COBRE, R25, and U54 training grants at Brown. She is the evaluator for NSF EPSCoR 192119 and knows the data and reporting requirements.

Mixed-methods will be employed for the collection of formative and summative data for this project. ***Interviews:*** Annual interviews will be held with the funded early career faculty members, community members, and personnel from the participating organizations, featuring a discussion of the relationship between community members and scientists, specific barriers and facilitators to training, the effectiveness of the collaborations, and the delivery, reach, and impact of the opportunities provided. ***Surveys:*** The various community members participating on the **CPRT** and **CKC** will be annually surveyed, focusing on the values and attitudes around specific climate issues, sense of trust and relationship building, collaboration, and whether the processes have been transparent and participants have been given equal voice and weight in discussions. Annual surveys of students and postdocs interacting with the project will focus on knowledge gain, mentee-mentor relationships, research self-efficacy, and intent to pursue climate research careers. Surveys after events and activities will provide immediate feedback to the program leadership and inform subsequent offerings, addressing the number of learning activities offered, number of participants attending, satisfaction with content, knowledge gained, and progress toward identified goals. Longitudinal follow-up surveys of participants will determine the lasting effects of the activities. Survey data will be collated in databases for evaluation and sharing.

The following metrics will be collected semi-annually to evaluate research collaboration strength: (1) advancing early career scientists, (2) 1-2 collaborative proposals per faculty member during the duration of this award, (3) 2-3 joint collaborative publications annually per faculty member, and (4) 1-2 scientific presentations per faculty member at conferences or workshops. Annually, the PI team and the RAB will review these metrics and advise corrective strategies including shifts in emphasis, incentivizing research productivity and collaborations, and reallocation of resources. Each year the career progression of the tenure-track early career faculty members will be evaluated as they attain tenure or prepare to do so.

The tracking system Dr. Kimberly uses for the other EPSCoR program will be adapted for this project. We will also cooperate with NSF, or its designee, to collect and share the prescribed centralized output data common to several EPSCoR projects in accordance with the format and timing from NSF.

5. Management and Implementation Plan (see Table 3 Timeline)

All activities across the jurisdictions will be coordinated by **Project Director (PD) Sarah Lummis** under the supervision of the five PIs. Specifically, the PD will organize **(a) weekly** 30m catch-up and coordination zoom calls with the entire Science Team (PI, senior personnel, postdocs, and students), **(b)**

		Year 1				Year 2				Year 3				Year 4			
	TASKs	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Community Knowledge Collective & Synthesis	Knowledge Input				Digital Database				Updates		Knowledge Synthesis					D6
2	SensorsNetworks & NERACOOS Integration		Codesign		Install 1		Codesign		Install 2		Codesign		Expansion				D1
3	Resilience Metrics, Synthesis & Projections	Metrics Co-Design			Develop & Test (TASKs 3,6,7 interact)						Projections			Synthesis			D2
4	Storylines & Scenarios, Evaluation & Synthesis		Surveying			Digital Storymaps					Evaluation & Updates			Synthesis			D5
5	CHAMP Modeling, Analysis, & Visualization System	System Expansion & Test				Hindcast		Projections			Dashboard Integration				Updates		D4
6	Data-Driven Models Linking Climate to Metrics		Covariability Analysis				CHAMP Integration				Projections						D2
7	Downscaling Climate Hazards Projections	Data Assembly			Downscaling Engine			CHAMP Integration			Senario Simulations			Scenario Synthesis			D3
8	6-12 Education Modules		Design				Deploy				Deploy			Deploy			D8
9	Training Students & Postdocs	Ongoing at all times															
10	Community Resilience Training Module		Develop module				Deploy module, improve, and activities to promote usage										D8
11	Local Decision Makers Bootcamps						Camp				Camp			Camp			D8
	Workshops		WS1				WS2				WS3			WS4			WS5

Table 3. Timeline & Milestones

monthly 1.5 hour project updates zoom calls that will include the CPRT, **(c) quarterly** calls to update and get feedback from the RAB - these calls will be attended by the PI and leads of the cross-disciplinary teams (see **section 3.2**), **(d)** oversee the development and update of the project website and a centralized web-based collaborative work environment and digital repository through Google Suite and Zoom (Brown has existing licenses). The PD will also oversee and provide direct support to the workforce development activities (**section 3.4**) and ensure the collection of all data & material for the evaluation plan to Dr. Kimberly (**section 4**). The PD is supported half time by this project and the other half time through the Institute at Brown for Environment and Society. PI **Di Lorenzo** will be responsible for overseeing all the **research TASKs** with the help of the cross-disciplinary team leads, each of which leads TASKs under their theme (see **section 3.2**). Co-PI **Maia** will be responsible for the **workforce development** activities and community liaisons. **Bowness** and **Rubinoff** will lead the **community relations** & communication. **Fox-Kember** is in charge of running additional weekly hybrid meetings at Brown with a rotating set of senior personnel to mentor students, postdocs, and early career scientists (see also **Postdoctoral Mentoring Plan**). The project workshops will be organized by the CPRT with support of the PD. The cross-disciplinary teams with across jurisdiction will organize their own meeting schedule and will report at the monthly calls.

6. Broader Impacts

(6A) Mentorship and Advancement of Early Career Scientists.This project team (55% women, 45% men) will mentor and advance the career of six early career research and assistant professors 5 women: Baker, Moretti, Bergen, Acton, Lummis, 1 male: Fairbanks, 1 person with documented disability: Acton), which represent 30% of the team. The PIs will also jointly mentor 5 postdoctoral level researchers (Brown: 2; UNH: 1; URI: 1; GMRI: 1) that span the social and natural sciences (see Postdoctoral Mentorship Plan) and four graduate students. Additionally, through the workforce development activity the project will provide internship and training opportunities for several undergraduate and 6-12 students from all the EPSCoR jurisdictions. **(6B) Infrastructures that increase Capacity for Resilience of Working Water-dependent Communities.** This project also will develop, and deliver tools for the broad spectrum of community participants key to resilience building. The eight EPSCoR infrastructures summarized in **Figure 3 (D1-8)** expand the capacity for coastal resilience science and planning of coastal populations - including local leaders, businesses, and residents - to support critical decision making along the New England Coast and beyond. Specifically, they span the following infrastructure types: data **(D1-2)**, modeling & analysis tools **(D3-D4)**, planning **(D5-6)**, training **(D7)**, and human **(D8)**. While these infrastructure elements are developed with our pilot communities, they are co-designed to be scalable and applicable to other regions. **(6C) Training and Building Expert Capacity in Local Communities.** In addition to the training of undergraduate students and the 6-12 Education modules, this project will develop on-demand material for a *Community Resilience Training Module* and *Local Decision Makers Boot Camps*, which will contribute to a nation wide effort led by the *Center for Sea Rise Solutions* (led by Mayor of Sausalito, CA) in collaboration with Mayors across the US to empower local officials to take adaptation actions against the threat of sea-level rise. **(6D) International Efforts for Coastal Resilience under the UN Ocean Decade.** The 3CRS framework will be shared as a US pilot contribution to the coastal resilience efforts of the *Global Ecosystem for Ocean Solutions* UN Ocean Decade Program under the SEAT'IES project and in coordination with the UN Decade Center for Coastal Resilience.

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