
Data Expeditions:
CLIMATE + HEALTH
Duke

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DISEASE BURDEN + CLIMATE RELATED DISASTERS

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ABSTRACT DISEASE BURDEN + CLIMATE RELATED DISASTERS

Climate change alongside unprecedented land use change disproportionately stresses the health and well-being of marginalized indigenous, rural and urban communities and the healthcare institutions that serve them remain woefully unprepared to respond. A better understanding of which health conditions are triggered by these shocks will help policymakers direct investment toward healthcare preparedness, targeting interventions to reduce impacts of climate-related disasters on people's lives. **We propose to develop health-climate data access capacity and explore how climate change-related hazards impact acute disease burden in rural Brazil and marginalized communities in the US South.** To achieve this goal, we will: (a) develop a repository combining healthcare data and climate data, following the FAIR principles (Findability, Accessibility, Interoperability, and Reuse); and (b) evaluate the association of climate-change characteristics, change in the burden of acute disease and gaps in healthcare capacity to address this impact. Our repository will include climate data (heat waves, cold snaps, extreme precipitation, etc.) from the National Oceanographic and Atmospheric Administration and health outcome data from the Duke University Health System and the Brazilian National Health Systems database (DATASUS). Our health data will focus on Emergency Care Sensitive Conditions (ECSC), defined as acute conditions that require timely access to care, which serve as good markers for the change in burden of care with weather/climate events (e.g. pulmonary associated conditions with heat, air quality, etc.). The repository will be built using a Knowledge Graph structure, improving its reusability and interoperability beyond the scope of this project.

With the repository developed, we will evaluate the frequency of ECSCs, as well as the capacity of the healthcare system to respond during climate-related events with a range of magnitudes and durations. This will include assessing for potential breaks in the continuum of care of emergency response facilities, in addition to measuring utilization and strain on the 9-1-1 system, Emergency Medical Services and Emergency Department resources. We will conduct similar evaluations in the US South (Durham/NC) and in Rural Brazil (Maringá/Paraná). We will conduct a set of time series analyses along with spatial variations in a Geographic Information Systems framework to account for significant changes in landscape and demographics to assess the impact on communities that are both more exposed to climate hazards and more economically/socially vulnerable. Once trends and correlations between climate impacts and disease burden are identified, we will 1) scale the analysis up to consider regional climate hazards/health outcomes in the Southeastern US and Amazonia, then nationally and 2) employ a set of Geospatial Artificial Intelligence, working with medical professionals to determine what resources should be pre-positioned in which communities to better treat ECSC during disasters.

THE SHIFTING CLIMATE AND THE EXPOSOME:

Using biological and wireless sensor networks and big data to predict and mitigate adverse global environmental health outcomes of climate change and pollution

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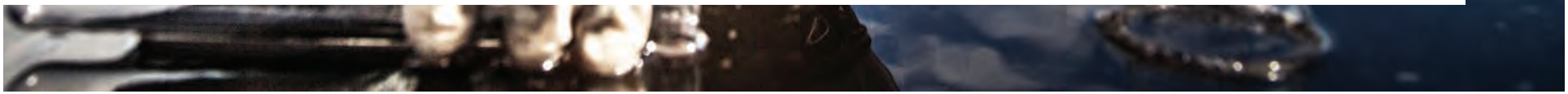

ABSTRACT THE SHIFTING CLIMATE AND THE EXPOSOME

We propose to predict and mitigate climate change and pollution driven health outcomes in low- and middle-income communities in Asia, Africa, and America by leveraging bioassays, low-cost sensor networks, and webtools (internet of things) to monitor air and water quality. We will utilize existing sensor networks and novel approaches for biomonitoring to investigate potential changes in the chemosphere associated with climate change. For example, water quantity and quality will diminish with increasing temperature and drought seasons, concentrating water contaminants. Air quality is predicted to worsen with climate change (e.g., increasing particulate matter in the air and changes in volatilized chemical compound levels). Low- and middle-income communities (LMIC), especially agricultural communities are heavily and disproportionately burdened by extensive chemical usage, while also being directly impacted by climate change driven shifts in temperature, rain, drought, and habitat suitability patterns. However, human health outcomes linked to shifts in the chemosphere with climate change in LMIC communities remain a critical knowledge gap. To address this important health disparity, we have assembled a team of researchers conducting research in global and local domains with expertise in air and water quality monitoring as well as community and occupational health. We propose to leverage existing research in (i) the CAFOS (Confined Animal Feeding Operations) in North Carolina, (ii) sugarcane and rice farming communities in South Asia, and (iii) agricultural regions in Kenya. We will utilize global satellite data, social media data, and ground sensor data to determine long-term climate trends. Sensor data, biomonitoring data (e.g., microbial community shift data and in vitro exposure assay data), non-target chemical composition data will be assessed for identifying exposome shifts. To determine adverse health outcomes potentiating from climate change induced chemosphere shifts, community health records will be mined and compared with climatological and exposome data. Results will develop a globally relevant robust framework and a sensor network for predicting and mitigating synergistic adverse health effects of anthropogenic environmental change.

CLIMATE CHANGE, RADON EXPOSURE AND LUNG CANCER

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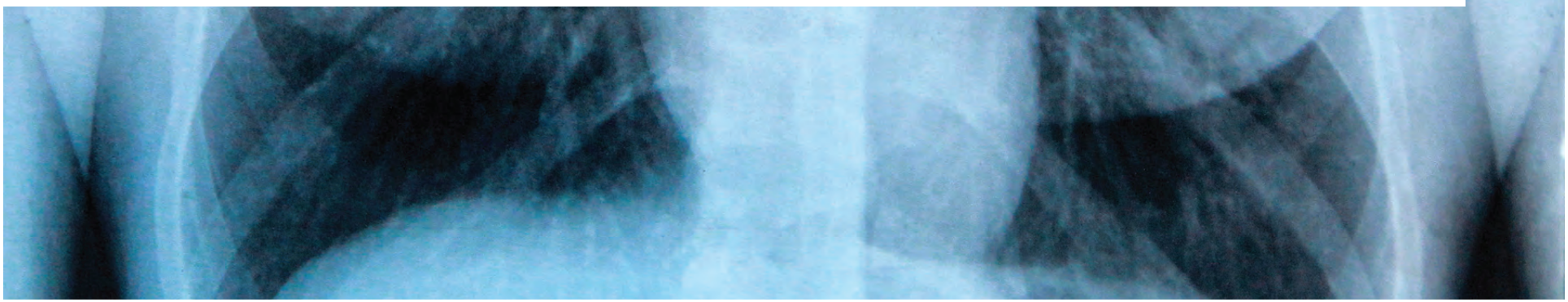


ABSTRACT CLIMATE CHANGE, RADON EXPOSURE AND LUNG CANCER

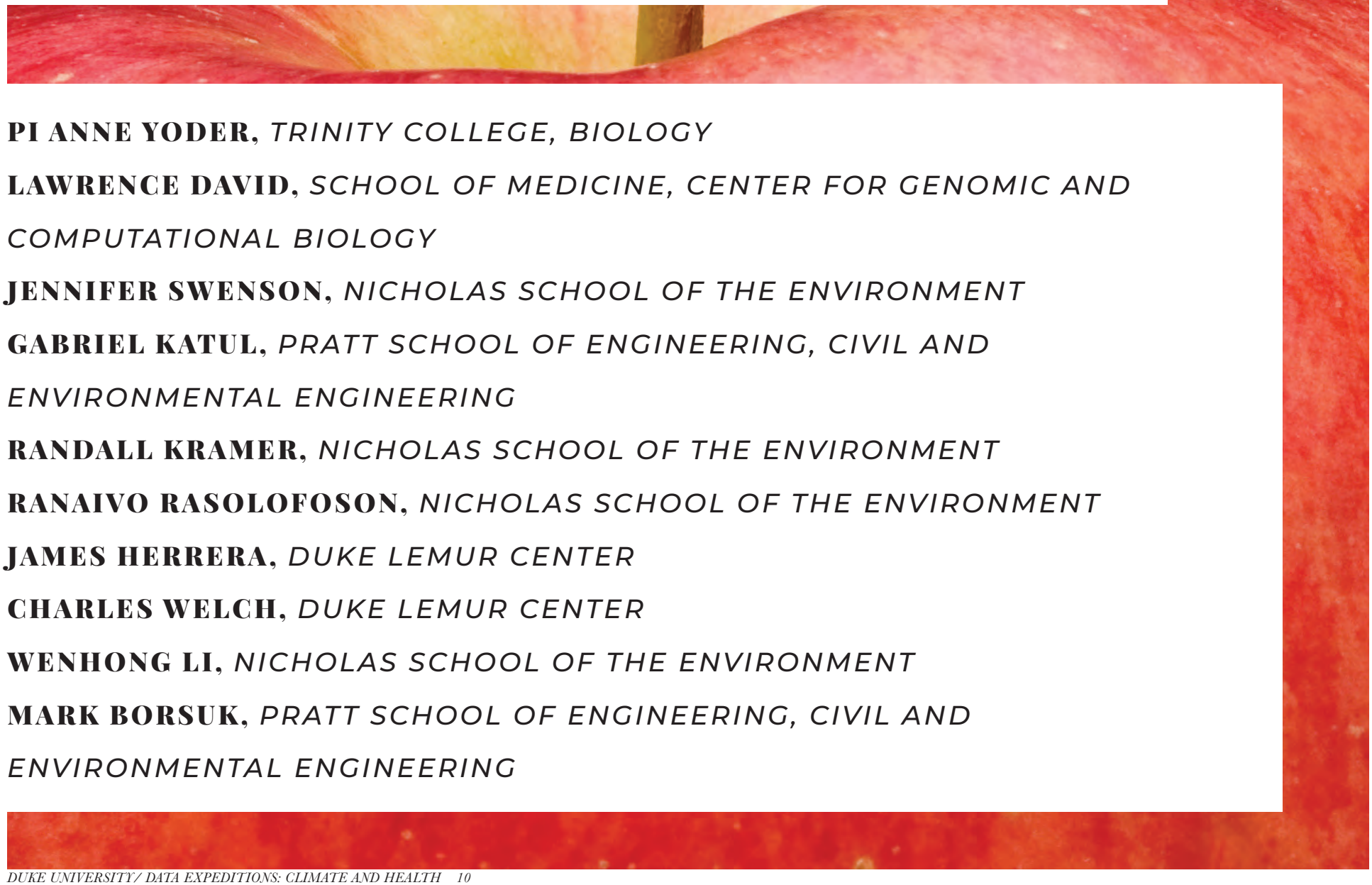
Racial Disparities in Radon Exposure, Awareness and Lung Cancer Risk in North Carolina Lung cancer is the leading cause of cancer deaths globally, in the United States and in North Carolina. Cigarette smoking is associated with 85% of all lung cancer cases, however 15-25% of cases occur in never-smokers. Exposure to radon, classified by the World Health Organization and the Environmental Protection Agency as a human carcinogen, is the second leading risk factor for lung cancer, and the leading cause of lung cancer among never-smokers. The risk of lung cancer mortality due to the lifetime exposure of radon at 4 picoCuries per liter of air is 7 in 1,000 for never-smokers, and 62 in 1,000 for smokers. While the prevalence of cigarette smoking has declined over the past few decades, rates of non-smoking associated lung cancer have almost doubled—increasing from 8% in 1990-1995 to 15% in 2011-2013, highlighting an urgent need to better characterize the impact of radon exposure on lung cancer risk and develop state-wide mitigation strategies.

Radon gas results from the decay of uranium and radium is found in most soil and rocks. Radon is drawn into buildings, causing prolonged exposure in the absence of radon remediation. Alarmingly, radon exposure is projected to increase over the coming decades due to direct and indirect effects of climate change. First, permafrost thawing due to increasing global temperature results in greater leakage of radon gas into the atmosphere and into residential buildings, leading to higher exposure. Second, increased air conditioning and fan usage, necessitated by increasing temperatures, leads to decreased air exchange rates in tightly sealed homes, increased radon concentrations on upper floors where residents spend greater amounts of time, and higher radon concentration and exposure. There are stark and concerning disparities in radon exposure; recent data from the BRFSS indicates that in 2019, only 14% of Hispanics had any knowledge of radon gas, compared with 37% of Black residents and 65% of White residents. Further, 68% of renters had no awareness of radon gas, compared with 37% of homeowners; and 88% of residents below the poverty level had no awareness of radon gas, compared with 29% of residents above the poverty level. Concerted strategies are needed to better characterize radon exposure among NC residents, develop programs targeting high-risk residents to raise awareness and promote the use of radon remediation, and monitor radon associated lung cancer risk in NC as the effects of climate change continue to spread globally. In this proposal, we will: 1. Characterize radon exposure, awareness, and testing among NC residents by race/ethnicity, gender, income, and neighborhood. We will integrate existing data from the BRFSS, EPA, and NC Department of Health and Human Services to generate predictive models identifying hot spots of radon exposure. We will also examine how these outcomes vary by key social determinants of health i.e., rural/urban, access to care, residential segregation 2. Examine the prevalence of radon mitigation approaches in NC by race/ethnicity, gender, income, neighborhood, and facility type (residential buildings, schools, hospitals). We will utilize existing data from the NC Multiple Listing Service (MLS) for residential buildings,

CONTINUED *ABSTRACT*
CLIMATE CHANGE, RADON EXPOSURE AND LUNG CANCER

and survey building managers for schools, large businesses, and hospitals to characterize use of radon mitigation approaches 3. Estimate the relative impact of smoking and radon exposure on lung cancer risk among NC residents. We will analyze incident lung cancer data from the NC Cancer Registry and examine the risk of lung cancer in regions characterized by high vs. low radon exposure, stratified by race/ethnicity and smoking status, to identify areas of high lung cancer risk.

ACCELERATING CLIMATE ACTION:
Nature-Based Solutions for Children's Health and Nutrition



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ABSTRACT ACCELERATING CLIMATE ACTION:

Nature-Based Solutions for Children's Health and Nutrition. Climate change will shape the future health of all communities, and it will deepen inequities. Climate adaptation and mitigation planning by countries cannot ignore health; doing so would result in tradeoffs and unintended consequences including disproportionate adverse impacts on women and children. As a result, a systems-based approach is needed to address climate, health and equity together –so that we can see the big picture, integrate knowledge, and identify interdependencies to target interventions while minimizing any adverse consequences. Undernutrition is responsible for 3.1 million deaths in children under 5 annually. Childhood undernutrition, from conception to a child's second birthday, is associated with motor and cognitive development problems that have adverse effects later in life, such as poor school performance, and limited long-term work and economic productivity. Maternal undernutrition, particularly during pregnancy, is associated with difficult labor, maternal mortality, and fetal growth restriction. Smallholder farm households in low-and middle-income countries (LMICs) are especially at risk because their subsistence strategies, which rely on predictable weather patterns, are not adapted to the changes we anticipate in future climates. The climate crisis is highlighting unsustainable food and nutrition policies and practices that are not only non-resilient to shocks, but also increase the likelihood of future shocks and exacerbate inequities. Half of the world's habitable land is used for agriculture, with food production accounting for 26% of global greenhouse gas emissions. The impacts of unsustainable food policies and practices on natural systems (e.g., forests, climate) feedback to affect food production and ultimately food and nutrition security, particularly of vulnerable groups such as women and children. With future climate change, the frequency and severity of droughts and tropical storms are predicted to increase, which amplify existing nutritional challenges, hunger and poverty crises in low-income countries

To break this feedback loop, comprehensive research and intervention programs should study and predict the likelihood of future shocks, and promote policies or interventions that reduce the frequency of shocks and strengthen resilience to those shocks when they occur. This can be achieved by integrating climate change mitigation and adaptation strategies that include forest conservation, landscape restoration, food production, and nutrition interventions to ensure that nutritional goals are not achieved at the expense of compromising the basic functions of natural systems (or "ecosystem services") on which human health depends. Multi-functional landscape mosaics characterized by patches of forests or trees intermixed with small-scale agricultural production systems have huge potential for reconciling climate change mitigation and human nutritional needs. Indeed soils and forests, including agroforests, are among the largest carbon sinks in the world. Multi-functional landscape mosaics also provide nutrient-rich foods and support diverse diets for women, young children and families, especially those living in rural communities. Integration of forest conservation, landscape restoration, food production, and nutrition interventions therefore offers a unique opportunity to deliver multiple co-benefits to

human health, nutrition, livelihoods, the environment, and the climate. Moreover, many forest conservation activities are often located where rates of undernutrition are high. The explicit integration of food and nutrition interventions into forest conservation can therefore provide public health benefits for some of the world's most vulnerable communities. The tropical island nation of Madagascar is renowned for its unique, but highly threatened, biodiversity. In the latest several years, the already high level of undernutrition has been exacerbated by more frequent and intense extreme weather, such as droughts and tropical cyclones. Madagascar is therefore a microcosm and early warning signal of what may happen to food security and nutrition of the world's vulnerable population when climate changes. Madagascar also presents a case study that is representative of global challenges, especially faced by the tropical LMICs and marginalized communities, and is an ideal site for integrating research and development on undernutrition, biodiversity conservation, and climate change. We propose to: 1) model the impacts of short-and long-term crises, especially natural disasters anticipated to worsen with climate change like droughts, floods, and tropical storms, on the resilience of rural communities in Madagascar. We will especially quantify resilience in terms of food and nutrition security, in relation to the services provided by forests, watersheds, and across the landscapes. By understanding the system dynamics of the feedbacks among livelihood strategies, forest conservation, public health, and the climate crisis, we can identify levers of action on which we can intervene to develop sustainable and restorative systems; 2) design, test, and evaluate the use of community forest management as a delivery platform to agriculture and nutrition programs. By offering a community-based delivery platform to agriculture and nutrition programs, community forest management will increase the likelihood of success at delivering food security and nutritional outcomes. Community forest management, in turn, can leverage the social co-benefits provided by agriculture and nutrition programs to incentivize local communities to participate in long-term forest management and conservation as mitigation and adaptation strategies.

WILDFIRE SMOKE EXPOSURE-RESPONSE [WiSER]

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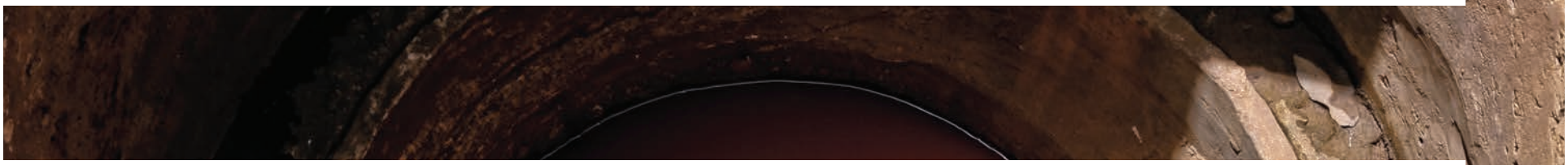
ABSTRACT WILDFIRE SMOKE EXPOSURE-RESPONSE [WISER]

Climate change is threatening the stability of global ecosystems and in turn harming human health. Over the past 15 years, population's exposure to wildfires has increased in 128 countries, yet the health impact of the smoke on exposed populations is not well described. We set out to investigate the exposure response function linking wildfire smoke and human health, to better describe the true scale and nature of this health impact. In particular, we aim to quantify the effect of wildfire smoke on populations living close to and far downwind of the fire, the impact of indoor air quality, and the variation in health effects between countries. We are combining healthcare data sets with emergency department visits, hospital admissions and mortality data for all of California and Singapore, as well as 90% of the Brazilian population. These will be analyzed with respect to incidence of cardiac, respiratory, cerebrovascular and thromboembolic emergency presentations and hospital admissions. These health data are being analyzed with respect to global atmospheric models from the GEOS-Chem collaborative, the European Space Agency, NASA fire spots from the MODIS satellite instrument and unique access to a network of 2 million indoor air quality sensors provided by a research partnership with Dyson. In time, results can be extrapolated along different representative concentration pathways. This work is being undertaken by a core team of epidemiologists at Duke's Critical Care and Perioperative Population Health Research center, atmospheric scientists at the Nicholas school and external data scientists. Californian and Singaporean health data are being analyzed in parallel through collaboration with the Californian EPA and Duke National University of Singapore, and the National Environmental Agency, Singapore.

A CONSORTIUM TO EFFECTIVELY RESPOND TO CLIMATE-ATTRIBUTABLE RISKS (ACERCAR)



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ABSTRACT A CONSORTIUM TO EFFECTIVELY RESPOND TO CLIMATE-ATTRIBUTABLE RISKS (ACERCAR)

Over the past decade, a Duke team supported by NASA developed and validated a malaria early warning system in the Peruvian Amazon. The system is based on three data streams: near real-time monitoring on hydrometeorology and land cover from a land data assimilation system (LDAS); weekly malaria surveillance in government health posts; and ancillary data that includes population at risk, recent interventions, and land concessions. While we have demonstrated high sensitivity and specificity in detecting outbreaks 8-12 weeks in advance as well as highly accurate "nowcasts" for small spatial areas; we have had challenges regarding: implementation and adoption; validation testing in countries on path towards malaria elimination; and leveraging the sophisticated climate models and teleconnections that improve terrestrial forecasts of climate characteristics. In addition, our regional partners in Latin America have indicated the need for improved visualization platforms of risks that are linked with climate/land cover data, validation of our general methodological approach for other diseases, and education/outreach to improve knowledge, interpretation, and decision-making of environmentally-driven health risks. This Duke Climate-Health Research team has the overall goal of improving disease early warning system estimates in multiple contexts, developing advanced visualization platforms in collaboration with our community partners, and designing an implementation science framework that includes capacity building to ensure scalability of our approach across Latin America and the Caribbean.

IMPACT OF CLIMATE CHANGE ON IMMUNE RESILIENCE

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ABSTRACT A CONSORTIUM TO EFFECTIVELY RESPOND TO CLIMATE-ATTRIBUTABLE RISKS (ACERCAR)

Extrinsic and intrinsic stimuli can shape a person's baseline immune response phenotype that impacts their responsiveness to vaccination and immunotherapy. Climate as an extrinsic factor can shape immune function and accordingly *climate change* is likely to alter the immune response in a variety of ways, but data remain severely limited. Identifying modifiable factors that can be targeted to improve human immune resilience is critical in promoting public health. Our team brings together Duke SOM, Nicholas School of the Environment, Pratt School of Engineering, Fuqua School of Business, School of Nursing, and Community with the ambitious goal of defining key environmental and intrinsic causes for human immune resilience and engineer interventions to optimally modulate immune function in a rapidly changing world.

We will focus on interrelated stimuli including climate and its shifting outcomes (environmental contaminant exposures, biological exposures and physiologic stimuli) evaluating which factors maximize or dampen immune resilience over the lifespan. Existing central North Carolina cohorts enable detailed longitudinal immune and environmental measurements.

Our primary technologies include the most cutting-edge assessments of environmental exposures, systems immunology, and engineering approaches to define variation in human immune responses to perturbations and stressors to build knowledge on how to augment and maintain immune resilience against climate change.

AIM 1 Engineer biosensors and the infrastructure to capture and integrate data streams from the environmental, biological, and physiologic stimuli.

AIM 2 Define and integrate systems immunology variables that are perturbed by extrinsic stimuli with baseline state (family and medical history, genomics and epigenomics, aging, and senescence).

AIM 3 Validate key extrinsic and intrinsic stimuli that perturb immune resilience through innovative engineering of biological materials (e.g., 3D printed tissues and organoids).

We broadly envision the design of personalized immune algorithms for informing clinical care and implementing new types of immune and environment sourcing data as part of community-based and individualized health decisions for immune resilience in the face of advancing climate change.

CLIMATE-ENVIRONMENT-HEALTH:
Zambia Kafue Ecosystem

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ABSTRACT CLIMATE-ENVIRONMENT-HEALTH: ZAMBIA KAFUE ECOSYSTEM

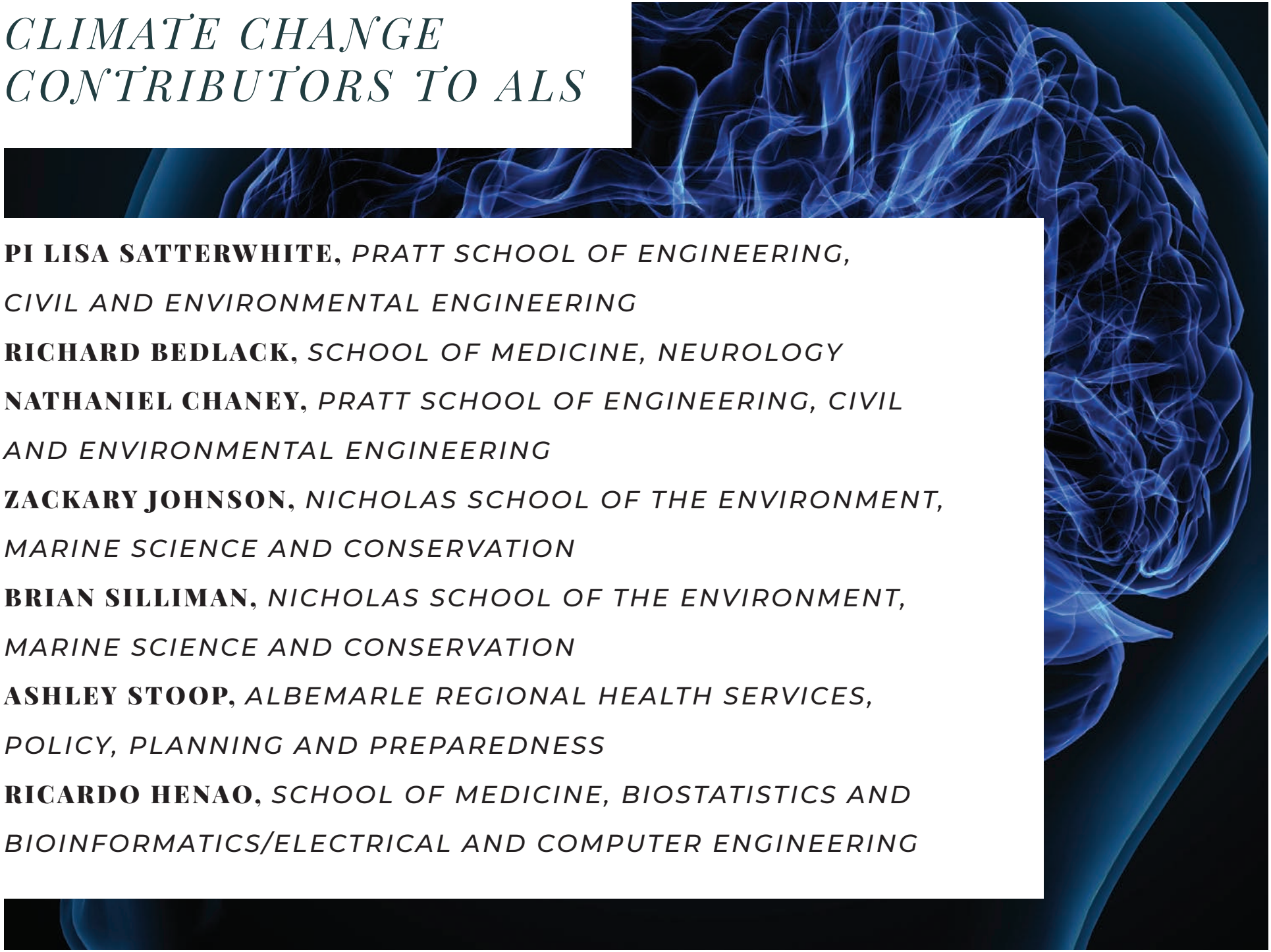
Climate change, environmental degradation, and health are deeply intertwined: climate change affects the environment in ways that can compromise the determinants of health – clean air, safe drinking water, sufficient food, and secure shelter. Climate impacts on the environment increase illness and death from extreme weather events, disruption of food systems, and increases in zoonoses and vector-borne diseases. Thus, the combination of climate change and environmental degradation can undermine the social determinants for good health, such as livelihoods, equality, and access to health care.

In sub-Saharan Africa, rural people are particularly at risk of experiencing the ill effects of climate change because of their high dependence on natural resources for income and for day-to-day survival. The economy of Zambia, for example, depends on climate sensitive sectors such as agriculture, resource exploitation, and tourism. This country of 17 million people suffers from frequent droughts, floods, extreme temperatures, and dry spells - and their frequency increases as the climate changes. Droughts in the 2018-19 farming season left 2.3 million people in need of emergency food assistance. Moreover, rainfall is projected to decline and temperatures to rise in the coming decades, reducing crop yields, and potentially increasing other environmentally harmful activities, such as deforestation for coal production, to meet their livelihood needs.

A critical assumption of the link between human well-being and conservation is that they have the potential to positively impact each other. Although there is a growing body of empirical work that indicates improved ecosystem health benefits human health, important knowledge gaps remain, and there is little to no empirical evidence to support claims that improvements in basic health will reduce or improve environmental health. Our study will rigorously assess the direction and magnitude of these linkages.

We will build a transdisciplinary team, strengthening existing relationships that some of our team members already have with government, international and local NGOs, and communities in Zambia's Greater Kafue Ecosystem. This ecosystem encompasses the Kafue National Park and nine locally managed Game Management Areas and is home to 200,000 people dependent on smallholder farming, fishing, charcoal production, mining, tourism, and timber. Our overarching goal is to determine how human well-being and conservation outcomes impact each other and the conditions that contribute to the realization of positive outcomes for both. To do so, we will (1) generate rigorous evidence to understand the mechanistic relationship between climate change, environmental health, and human health; and (2) design and evaluate solutions to strengthen the adaptive capacity of rural communities to respond to climate change by building sustainable livelihoods and green local economies.

CLIMATE CHANGE CONTRIBUTORS TO ALS



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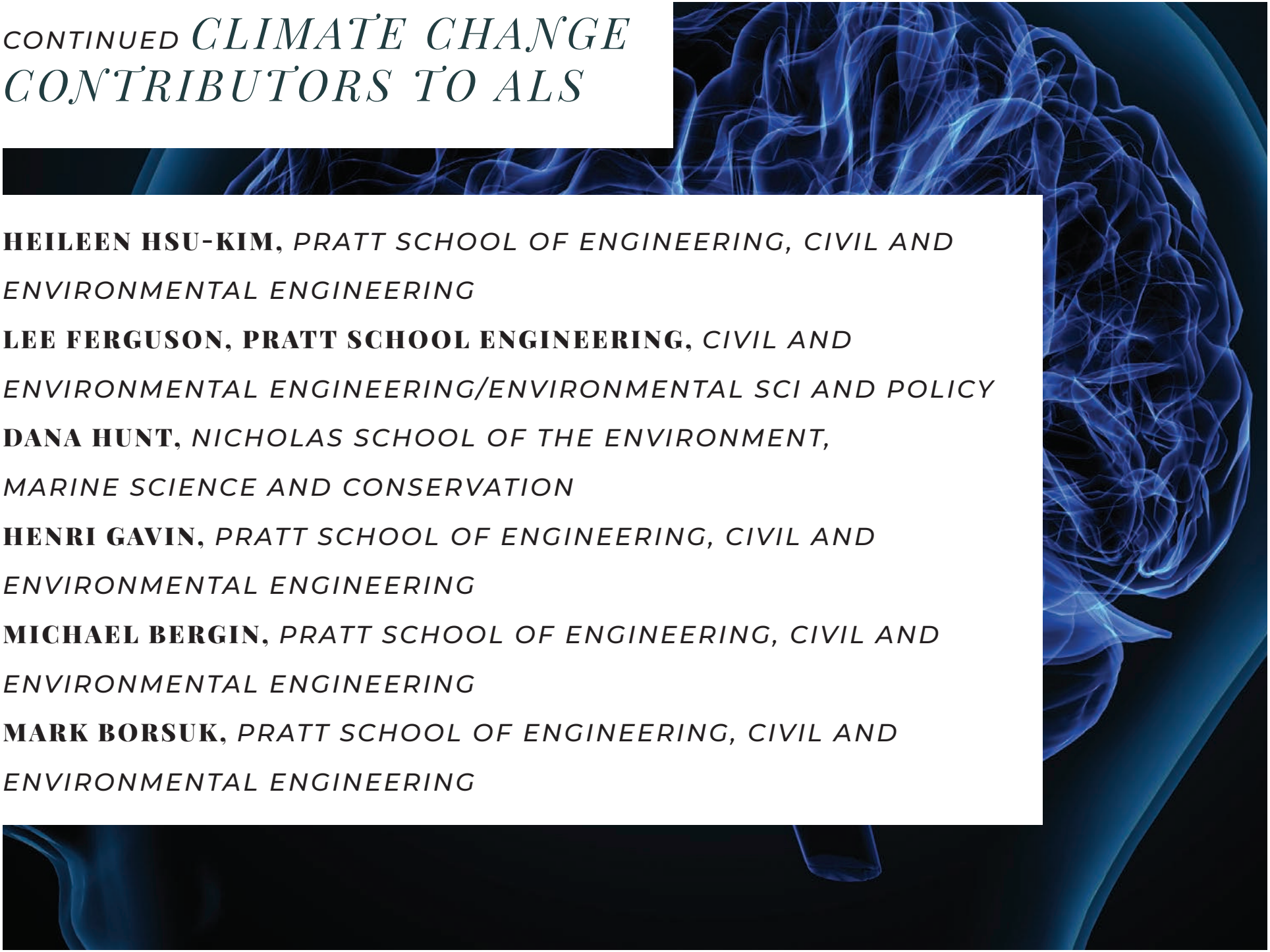
CONTINUED *CLIMATE CHANGE CONTRIBUTORS TO ALS*



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ABSTRACT CLIMATE CHANGE CONTRIBUTORS TO ALS

Climate Change Contributors to ALS will explore the relationship between climate change and neurological health in a study of amyotrophic lateral sclerosis (ALS, Lou Gehrig's disease). ALS is a devastating neurodegenerative disease without cure, with the majority of cases idiopathic, or of unknown cause. Geographical clusters of ALS have been linked with cyanobacteria (blue green algae) blooms, a type of harmful algal bloom that releases a strong neurotoxin, beta-methyl-amino-L-alanine (BMAA), that accumulates in air, water and food. BMAA is a homologue of the amino acid serine and is incorporated during protein synthesis, resulting in mis-folded protein tangles which are observed in motor neurons of people with ALS. As the number, sites and intensity of harmful algal blooms potentially increase with climate change due to warming and precipitation extremes (nutrient runoff), our concern is that blooms will negatively impact neurological health to such an extent that we will see increased occurrence of ALS in local human populations. Our objective is to determine how neurological health is influenced by climate change. We will partner with Albemarle Regional Health Services to study an apparent ALS cluster in the Albemarle Sound region to create a scalable model to test how climate change can drive degradation of human health and how natural ecosystems can mitigate this impact. We will test the general hypothesis that climate-change driven harmful algal blooms (HABs) will lead to decreased neurological health and increased occurrence of ALS and that the natural extent and restoration of NC coastal ecosystems can mitigate these negative impacts on human health.

AIM 1 is a retrospective study to determine the relationship between cyanobacteria blooms (number, size, duration), climate parameters (temperature, precipitation, streamflow discharge) and ALS (prevalence and incidence). We will leverage two decades of satellite remote sensing, historical climate data and ALS case and mortality data over the region to test the *hypothesis* that climate change-driven effects are associated with both an increased HAB occurrence and the number of ALS deaths. This Aim addresses one challenge in climate health research: the need for a multi-decade longitudinal data acquisition to accurately describe a relationship.

AIM 2 is a prospective study to test the *hypothesis* that HAB-associated ALS looks different, either clinically or molecularly, compared to ALS that is not HAB-associated. We will collect demographics, disease characteristics and biological samples from people with ALS and their spouses/caregivers living near active blooms compared to those in urban areas without exposure. Biological samples will be used to identify underlying molecular mechanisms in the form of gene expression, epigenetic signatures and metabolites of chemicals and toxins. Differences could strengthen the case for a causal relationship between HABs and ALS, and potentially identify unique ways to diagnose ALS, treat the subset of HAB-associated ALS, and predict ALS disease progression. Additionally, environmental sampling will determine specific organisms and toxins that are associated with ALS.

AIM 3 is a study of how coastal wetland extent (oyster reefs, marshes, swamps) and restoration will mitigate climate change driven HABs and

ALS prevalence on the NC coastal plain. Using spatial correlations and modeling we will test the *hypothesis* that the natural extent of coastal wetland ecosystem and modeled restoration can reduce frequency and incidence of HABs and ALS in the Albemarle Sound region. This aim will develop drone imaging and continuous remote environmental sensing of air and water to lay groundwork for a future project aimed specifically at reducing neurotoxins through large scale ecosystem restoration.

Our study is innovative in applying both ecological and clinical approaches to solve a climate scale problem. Deliverables will be high resolution maps of climate, blooms, and ALS over two decades, blood diagnostics for ALS and cyanobacteria toxin exposure, and wetland restoration models that will describe methodology for removing neurotoxins from the environment through maintaining ecosystem health. We are excited to develop an empowering two-way collaboration with Albemarle Regional Health that will include a patient advisory board, citizen scientists to conduct environmental sampling, and community events that will bring together ALS patients and their families, clinicians and foundations that serve them with the wetland restoration experts who will help them safeguard their environments. We see community engagement as the essential link between discovery and implementation.

We envision this study as the start of a three-decade partnership that will build climate resilience into our land use in rural areas where climate change impact is most severe and where people are least able to combat the negative health effects. This is a now or never moment to work together to build logistics that will empower these communities. We are solution-based optimists, committed to healing our planet and our people.