

Seminar on the Consequences of Climate Change on Health at Older Ages

The National Academies of Sciences, Engineering, and Medicine
Committee on Population

May 9, 2022

Zoom Conference

Revised February 9, 2023



This meeting summary was prepared by Rose Li and Associates, Inc., under contract to the National Institute on Aging (NIA). The views expressed in this document reflect both individual and collective opinions of the meeting participants and not necessarily those of NIA. Contributions to this meeting summary by the following individuals is gratefully acknowledged: Tomas Pitfield, Dana Carluccio, Elizabeth Frankenberg, Vijay Limaye, Ayesha Mahmud, Emerald Nguyen, Anne Pebley, John Phillips, Noah Webster

Table of Contents

Executive Summary	iii
Effects of Extreme Heat, Cold, and Weather on Older Adult Health	iii
Increases in Climate-Related Infectious Disease Prevalence	iii
Impacts of Climate on Older Adults' Financial Stability and Security	iv
Cognitive and Psychological Effects of Climate Change on Older Adults	iv
Meeting Summary	1
Introduction	1
Effects of Extreme Heat, Cold, Weather Events, and Older Adult Housing on Health	2
Temperature Risks to Older Adults	2
Research Needs	3
Discussion	4
Effects of Increases in Climate-Sensitive Infectious Disease Prevalence on Older Adults	5
Climate Change and Infectious Disease	5
Impact on Older Adults	5
Future Research Directions	6
Discussion	6
Impacts of Climate on the Financial Stability and Security of Older Adults	7
"New Normal" of Climate Change	7
Social and Economic Impacts of Climate	7
Discussion	8
Cognitive and Psychological Effects of Climate Change on Older Adults	10
Urban Flooding	10
Smart Stormwater Systems	10
Green Infrastructure	11
Risk and Resilience	11
Data Needs	12
Discussion	12
Panel Discussion	13
Data Needs	13
Appendix 1. Meeting Agenda	16
Appendix 2. List of Participants	17

Executive Summary

On May 9, 2022, the National Academies of Sciences, Engineering, and Medicine convened an expert panel to address the Consequences of Climate Change for Health at Older Ages. The panel's four presenters provided insight into the negative health impacts of climate change and climate-related weather events on older adults, including the effects of rising temperatures on chronic disease increasing infectious disease rates, greater economic instability, and negative effects on cognitive health and wellbeing. Presenters emphasized that greater funding and innovation in public health research are essential to better understand, predict, and respond to the climate-related risks that older adults face as one of the most vulnerable demographic groups nationally and globally.

Effects of Extreme Heat, Cold, and Weather on Older Adult Health

Global climate change and rising temperatures pose a greater risk to older adults than to most other age groups primarily through heightened exposure risks, limited adaptive responses, and compounding economic and social inequities. Older adults have a decreased physiological ability to regulate body temperature and are more likely to have chronic health conditions that may be exacerbated by extreme heat events. Moreover, older adults, particularly those with dementia, may have difficulty communicating heat-related discomfort. Older adults may also have greater social vulnerability to climate change, due to social isolation from early warning systems. They may also have limited and/or fixed incomes that may increase risk of living in substandard housing without access to adequate indoor climate control. Lastly, many older adults lack access to adequate healthcare to treat medical conditions caused or exacerbated by heat.

Research Opportunities

1. Encourage research into the links between climate change and neurological disorders.
2. Integrate data from multiple sources at the local, state, and federal levels to cross-reference health outcomes with climate and extreme weather event data.
3. Engage appropriate organizations at the local, state, and federal levels to improve and integrate emergency planning processes.
4. Evaluate ways to improve support systems for older adults during and after extreme weather events and crises.
5. Develop climate-related education materials on care and preparation for extreme weather events for older adults, their families, and formal and informal caregivers.

Increases in Climate-Related Infectious Disease Prevalence

Older adults will be disproportionately affected by rising rates of climate-related infectious diseases through increased susceptibility to infection and susceptibility to disease-related economic disruptions, especially among those with low-income and racial/ethnic minorities. Immunosenescence, malnutrition, and other physiological changes put older adults at increased risk not only of infection, but also of mortality and morbidity following infection. Given the

current and predicted rising rates of infectious disease due to climate change, the prevalence of infectious disease will increase asymmetrically among older adults.

Research Opportunities

1. Encourage research on the mental health effects of infectious disease management, including physical distancing, on older adults.
2. Evaluate ways to improve healthcare system preparedness and quality of care for older adults with greater susceptibility to infection, especially those with chronic autoimmune conditions or respiratory illness.
3. Encourage research to characterize the physical, social, and economic burden of climate-related infectious disease on older adults.

Impacts of Climate on Older Adults' Financial Stability and Security

Older adults appear to be less economically resilient to climate-related extreme weather events and natural disasters. Compared to younger adults, older adults typically recover more slowly and to a lesser extent following natural disasters. Natural disasters can cause damage to property that older adults may find difficult to repair on a fixed income, potentially wiping out retirement savings; the alternative of relocation may be financially impossible or practically infeasible. Older adults can also lose short- or longer-term access to caregivers and social support systems during and after extreme events, leaving them more broadly vulnerable.

Research Opportunities

1. Encourage research into how mid-life preparations for older age (e.g., retirement savings, housing adequacy, and social support networks) can moderate climate change impacts.
2. Encourage research into economic and social recovery from large, negative events (fires, drought, extreme storms), both acute and recurring, to identify impacts on older adults and strategies to improve resilience.
3. Consider the larger-scale regional implications of changes in things like agricultural and labor productivity for population health and well-being and to determine whether older adults are differentially at risk.
4. Encourage research into migration, relocation, and housing adaptations in response to climate-related weather events to identify ways to protect older adults who may be unwilling or unable to move from high-risk regions.

Cognitive and Psychological Effects of Climate Change on Older Adults

Climate-related stressors such as increasing heat, decreasing air quality, and more frequent and severe extreme weather events all disproportionately worsen cognitive and psychological health among older adults. Extreme heat, particularly during the night, can interrupt restful sleep and decrease cognitive health and psychological wellbeing. Mobility issues prevalent among older adults pose barriers to proactive preparation and reactive response to extreme weather events like flooding, leading to increased anxiety and poor cognitive health. Although some research suggests that older adults may be more psychologically resilient, reporting less anxiety and concern about increased urban flooding, these lower levels of anxiety and concern

may instead reflect unawareness of or resignation to potential flood-related damage. Older adults may feel resigned to flood damage in part because of mobility and/or financial limitations, which may make repairs difficult. Infrastructure programs such as urban rain gardens, designed to reduce flooding, may be useful tools to mitigate urban flooding with additional social and mental health benefits to community members. Additionally, although climate change poses greater risks to older adults, it also offers new opportunities for older adults to volunteer and engage in their communities, potentially leading to positive mental health/cognitive outcomes.

Research Opportunities

1. Leverage existing data from ongoing and future longitudinal studies that collect age in order to integrate health, economic, and momentary ecological assessment data as climate-related events occur and as a means of increasing research into the effects of climate change on older adults.
2. Follow up with participants from existing surveys in communities exposed to extreme climate events to better understand the effects of aging on social, economic, and medical wellbeing.
3. Include modules and standardized measures assessing experiences and anxiety/distress related to climate change in ongoing, population-level studies.
4. Increase sample sizes of older populations in ongoing and future studies to better understand the heterogeneity of older populations' climate-related risk and intersections with race, ethnicity, and socioeconomic status (SES).
5. Encourage more longitudinal studies and primary data collection focusing on older adults' experiences from climate-related events, such as fires and flooding.

Meeting Summary

Introduction

Emerald Nguyen, Ph.D., Social and Behavioral Science Administrator, Population and Social Processes (PSP) Branch, Division of Behavioral and Social Research (BSR), National Institute on Aging (NIA), National Institutes of Health (NIH).

The National Institute on Aging (NIA) commissioned the Committee on Population (CPOP) to convene a meeting to present findings related to the impacts of climate change on the health of older adults, which is a priority research area for both the NIA and the Division of Behavioral and Social Research (BSR). The meeting was held via web conference on May 09, 2022. The meeting agenda and list of participants are included as Appendices 1 and 2, respectively.

In its [2019 review of BSR-funded research](#), the National Advisory Council on Aging (NACA) recommended that BSR prioritize research to better understand the health impacts of climate change on older adults as a macro-social factor of aging. Climate change-related health impacts are relevant to several of NIA's Strategic Goals. Impacts on social factors of aging connect to [NIA Strategic Goal B](#), which calls for understanding the effects of personal, interpersonal, and societal factors on aging, including the mechanisms through which these factors exert their effects; in addition, predicted impacts on increases in health disparities connect to [NIA Strategic Goal F](#), which calls for understanding health disparities related to aging and developing strategies to improve the health status of older adults in diverse populations. NIA, through two past funding opportunity announcements, awarded [six projects](#) that address three areas of climate change (two projects per area): natural disasters, heat, and wildfire. NIA is also involved in the National Institutes of Health (NIH) [Climate Change and Health Initiative](#), the [Intra-NIH Disaster Interest Group](#), and the Department of Health and Human Services (HHS) [National Advisory Committee on Seniors and Disasters \(NACSD\)](#).

Older adults, individuals with disabilities, including chronic diseases and mobility issues, are especially vulnerable to negative health impacts—excess morbidity and mortality—associated with climate-driven extreme weather, disasters, elevated temperatures, decreased air quality, and increases in climate-related anxiety. The 2020 [Lancet Countdown](#) found a 53.7 percent increase in heat-related mortality in people older than 65 years over the past 20 years, resulting in approximately 300,000 deaths in 2018. The four expert panelists presented their findings and facilitated discussions on topics specifically related to the impact of climate change on the health and morbidity of older adults.

Effects of Extreme Heat, Cold, Weather Events, and Older Adult Housing on Health

Vijay Limaye, Ph.D., Senior Climate Change & Health Scientist, Science Office, Natural Resources Defense Council (NRDC)

According to the Intergovernmental Panel on Climate Change (IPCC), the climate crisis has reached new extremes on many measures of climate change, with the highest CO₂ concentration in at least two million years, the fastest rate of sea level rise in at least 3,000 years, the lowest level of Arctic Sea ice area in at least 1,000 years, and the level of glacial retreat unprecedented in at least 2,000 years.

Although the climate crisis may not appear to be a direct public health crisis, temperature rise (+ 2-3° C by 2100), sea level rise, and hydrologic/weather extremes have many downstream impacts on public health, including (1) the urban heat island effect, which increases heat stress and cardiorespiratory failure; (2) air pollution, which increases rates/severity of respiratory diseases (e.g., COPD, asthma); (3) vector-borne diseases such as malaria, dengue, encephalitis, hantavirus, Rift Valley fever, and more; (4) waterborne diseases such as cholera, cyclosporiasis, cryptosporidiosis, campylobacteriosis, leptospirosis, and more; (5) threats to water resources and food supply, causing malnutrition, starvation, and diarrhea; and (6) displacement of environmental refugees, leading to forced migration, overcrowding, and increases in human conflicts and infectious diseases. *Nature: Climate Change* recently published a study ([Vicedo-Cabrera et al, 2021](#)) that found that “across all [43] study countries ... 37.0 percent (range 20.5-76.3 percent) of warm-season heat-related deaths can be attributed to anthropogenic climate change and that increased mortality is evident on every continent.”

Temperature Risks to Older Adults

Climate and demographic changes converge in ways that exacerbate threats to older individuals. Social isolation and limited income can heighten exposure risks and limit available adaptation responses. Heat exposure increases the risk of illness and death in older people, though specific risks to people with dementia have not been sufficiently studied.

Heightened Exposure Risks

Older adults are at heightened health risk from exposure to heat. Not only do older adults have reduced thermal regulation, but heat may interact with medications and can exacerbate confusion, disorientation, mental stress, and anguish in older adults, especially those with dementia. Ultimately, heat is not merely an inconvenience but threatens organ systems throughout the body. Moreover, clinicians lack training in these climate-specific health risks.

Compounding Inequities

Non-climate related inequities facing older adults are compounded by climate change. Heightened temperatures, especially during summer months, can cause environmental stressors, such as increased air pollution and ozone levels, that exacerbate respiratory issues

disproportionately affecting older adults. Many older adults lack access to affordable care, decreasing their ability to seek treatment for medical conditions worsened by climate change.

Limited Adaptive Responses

Older adults are also less able to adapt/respond to heat exposure. Social isolation and mobility constraints can compound the effects of heat exposure for many older adults and limit their ability to take precautions against extreme heat events. Socially isolated older adults may be unable to access support networks during a crisis, may remain unaware of public warnings of impending heat events, and may lack assistance from caregivers to meet health, food, hydration, and medical needs. Similarly, older adults, especially those with dementia, may have greater difficulty communicating their discomfort and hydration needs. Furthermore, older adults may be more economically vulnerable, and many reside in substandard housing conditions.

Adaptation Agenda for Older Adults

A strategy is needed to better help older adults and informal caregivers properly plan and prepare for mounting climate risks. Such a strategy would include (1) engaging appropriate local, state, and federal agencies in the emergency planning process; (2) supporting older adults during and after an acute hazard; (3) providing older adults and informal caregivers with education on emergency and extreme climate preparedness; and (4) supporting professionals who can help older adults and their informal caregivers prepare for climate hazards.

Research Needs

Climate and public health research priorities should adapt to adequately address the effect of climate change on health. The current lack of research impedes awareness of, and responses to, major public health issues, especially those affecting older adults, which are exacerbated by mounting climate change. One recent review ([Amiri et al, 2021](#)) was unable to find any studies on the effects of climate change/heat on neurological conditions. Although the National Oceanic and Atmospheric Administration (NOAA) does track the annual financial costs associated with extreme weather events, it does not specifically track the cost of heat-related mortality and morbidity. The Natural Resources Defense Council (NRDC) recently published an ongoing study ([Limaye et al, 2019](#)) that uses publicly available health data to estimate health-related financial costs of climate-related events, including deaths, medical care, outpatient care, home health care, and prescribed medications, as well as lost wages. Because public health data are fragmented, the NRDC study must integrate information from several local, state, and federal sources—Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), and NOAA—to holistically measure the financial burden of mortality and morbidity caused by events worsened by climate change. NRDC has calculated a \$10 billion health cost from ten climate-related events alone in 2012, with the disproportionate majority (64 percent) of the illness-related costs shouldered by Medicare and Medicaid patients.

Climate & Health Goals

The four primary goals of addressing climate-related health burdens are: (1) improve understanding of climate-related cost burden on individuals, families, employers, insurers, and governments; (2) demonstrate the health and financial benefits of a robust response to the climate crisis; (3) invest in staff and partnerships to further local understanding of climate-worsened health harms; and (4) improve public health surveillance data systems and deployment of adequate technology to track this growing threat.

Discussion

More research is needed to address the disproportionate impact of climate change on US territories with large and vulnerable minority populations at heightened risk of climate-related extreme weather events.

Climate Change in U.S. Territories

More research is needed to address the disproportionate impact of climate change on US territories with large and vulnerable minority populations at heightened risk of climate-related extreme weather events. The 2017 Hurricane Maria, for example, highlighted the lack of infrastructure in Puerto Rico to monitor excess deaths. However, people living in U.S. territories—all of which are islands—appear to have higher public awareness of climate change risks compared to those in the continental United States.

Access to Air Conditioning

Older adults may have less access to air conditioning (AC) and higher energy insecurity compared to the general population. Furthermore, older adults with lower income may be reluctant, for financial reasons, to use AC even if they have access. The higher night-time temperatures that result from these trends can disrupt sleep and exacerbate dementia and related conditions. These effects may compound health disparities: for example, African Americans have lower incomes and higher levels of dementia compared to white Americans. A recent survey on AC prevalence/access also identified 12,000 excess deaths due to chronic heat from 1950-2018. The federal Low Income Home Energy Assistance Program ([LIHEAP](#)) intends to address the financial burden of and lack of access to AC.

Air Quality Disparities

Low air quality may disproportionately affect older adults, whose lower and fixed incomes may render them more likely to live near highways and industrial sites with poorer air quality. These effects may be particularly pernicious for racial and ethnic minorities, both because of lower average income and because of a long history of residential segregation by race. Researchers can collaborate with principal investigators (PIs) of existing study cohorts to investigate the relationships between rising heat, declining air quality, and neurological disorders. Air quality data are widely available and useful in these collaborations. Research funding is improving, but more interdisciplinary collaboration is still needed.

ICD Codes in Climate Health Research

Common data elements can be prioritized when integrating data sets. The NRDC study ([Limaye et al, 2019](#)) used International Classification of Disease (ICD) codes to integrate diagnoses and causes of death into their model. ICD coding could be a useful tool in public health data reporting. Research would benefit from increased reporting in journals of cause of death information in assessments of mortality data.

Effects of Increases in Climate-Sensitive Infectious Disease Prevalence on Older Adults

Ayesha Mahmud, Ph.D., Assistant Professor, Department of Demography, University of California Berkeley

Climate change can increase prevalence of infectious diseases; although these diseases are not a direct focus of NIA, they impact older populations' mental health — including their risk of loneliness, social isolation, depression, and cognitive — in ways that do intersect with NIA priorities. Highly prevalent and rapidly spreading infectious disease epidemics can also reduce access to care for older adults with chronic diseases by rapidly increasing demand for health services, as occurred in the early years of the COVID-19 pandemic.

Climate Change and Infectious Disease

Global climate and demographic changes influence the prevalence and spread of infectious diseases through the processes of pathogen emergence, disease dynamics, and global transmission ([Baker and Mahmud et al, 2021](#)). A new era of infectious diseases is beginning, defined by greater frequency of outbreaks of emerging, re-emerging, and endemic pathogens that spread quickly, aided by global connectivity and climate change-driven expansion of pathogens' geographic range. Changing environmental conditions may also increase the risk of pathogen spillover through altered species range and density, leading to novel interactions between species; for example, virologists hypothesize that this phenomenon drove the emergence of pulmonary hantavirus in 1993.

Indirectly, climate change is predicted to increase the burden and frequency of outbreaks and respiratory pathogens. Temperature and humidity shifts can change the timing and severity of seasonal outbreaks of respiratory diseases (e.g., influenza), while increased precipitation and flooding events can drive more frequent outbreaks of enteric/diarrheal diseases (e.g., typhoid). More frequent extreme weather events, population displacement, and disruption of the healthcare system will all affect outbreaks. Interaction with air pollution in rapidly urbanizing countries could also increase the burden of respiratory pathogens.

Impact on Older Adults

Increased climate-related infectious diseases have direct and indirect effects on the health of older adults. Infectious diseases in older adults are typically more frequent and more severe

due to immunosenescence, malnutrition, and age-related physiological and anatomical changes ([Gavazzi et al, 2002](#)). Older adults will likely bear disproportionate climate-induced increases in infectious disease risk and burden, including higher rates of morbidity and mortality.

Mental health impacts of infectious disease include loneliness, social isolation, depression, and cognitive decline. Chronic conditions may be exacerbated by lack of access to treatment brought on by the heavy demands that infectious disease epidemics can place on health services. Economic disruptions caused by major infectious disease outbreaks may deplete retirement savings and affect financial planning. Low-income communities and racial/ethnic minorities may disproportionately bear both the direct and indirect impact of disease outbreaks.

Future Research Directions

Understanding the socioeconomic consequences of increased and/or shifting patterns of infectious disease burden on older adults is crucial. Current research is lacking on the contribution of infectious disease burden to mental health, including the impact of physical distancing measures. Future research could also investigate the disparate impacts of climate change and disease burden on older adult populations in vulnerable communities. Quality of care and preparedness of healthcare systems are essential for aging populations with chronic conditions, comorbidities, and increased vulnerability to novel and endemic pathogens in the face of frequent large scale outbreaks of infectious disease.

Discussion

Health Impacts of Early Life Climate Impacts on Later Life

Most research on the impact of early life infections on health outcomes later in life focuses on malaria and influenza. The [CenSoc](#) project from the University of California Berkeley is currently conducting related research to update older studies. Some studies are also exploring the effects of temperature and air pollution on preterm births and newborn health, but not on older adult health.

Country of Origin and Urban Segregation

Surveys investigating large populations seldom inquire about participants' country of origin, potentially missing the effects of climate-related events and temperature on mid-/early-life health experienced prior to immigration. Location is also relevant even for those who have always lived in one country or even city. Cities are not homogeneous, but rather often highly segregated, leading to differences and disparities between the experience of climate-related health issues from one location to another. For example, decreased air quality and increased flood risk lead to higher rates of dengue in flood-prone neighborhoods, especially among those with lower SES. Population segregation by SES can also affect mental health through a loss of sense of community, which can affect psychological resilience.

Climate Change and Urinary Tract Infections

Rates of tick-borne diseases and some urinary tract infections (UTIs) are also sensitive to

climate change. However, UTIs may be caused by a wide range of pathogens, complicating studies of the direct relationship between climate change and pathogen prevalence.

Lessons Based on COVID-19

The impact of climate change on social isolation was a common theme in the first two presentations. Recent survey research at the University of California Berkeley on mental health, mood, and social isolation found that social isolation and mobility issues related to COVID-19 were rampant. Community programs that exist outside the public health sphere could offer a useful intervention to address social isolation and its downstream negative health impacts. The COVID-19 pandemic provided public health researchers an opportunity to investigate the efficacy of community programs for reducing social isolation, although not necessarily the quality of specific programs.

Survey Technologies

The effectiveness of survey platforms is country-specific, especially for reaching older adults most vulnerable to climate change. Traditional phone or internet surveys that work in the U.S. have sometimes received lower response levels abroad. In Bangladesh, compared to internet surveys, mobile phone-based surveys that permit text responses have been more effective.

Impacts of Climate on the Financial Stability and Security of Older Adults

Elizabeth Frankenberg, Ph.D., Professor, University of North Carolina at Chapel Hill, Director, Carolina Population Center

"New Normal" of Climate Change

Physical dimensions of climate change and related climate shocks (e.g., wind, precipitation/drought, humidity, temperature, sea level, ground saturation) interact with other relevant event parameters (e.g., speed of onset, predictability, duration, scale, chronic vs. acute) to cause a variety of impacts (e.g., property damage, exposure to physical threats, change in work opportunities, disruption of daily activities and social networks, reduced access to healthcare, rising prices) that can directly affect the economic and social wellbeing of populations, especially older adults. Climate shocks are increasing in frequency and intensity, creating a "new normal" in the United States. This new normal includes rising temperatures and sea levels; a wetter Eastern US and drier Western US; increasingly frequent and stronger fires, storms, and hurricanes; and more overall climate variability. Current research efforts must determine whether the biology of aging and age-related changes in SES diminish older adults' ability to respond and adapt to new conditions created by climate change.

Social and Economic Impacts of Climate

Assessing the social and economic impacts of climate change requires a targeted system of accurate measurements and methods, not only of climate-related physical forces, but also of

longitudinal data collected from populations both before and after a climate event. This data set up supports estimation of “dose-response” relationships to answer questions about how intensity of exposures and experiences shapes outcomes.

Beyond effects on individuals and outcomes, climate change can impact larger-scale systems. For example, effects of climate change include reduced agricultural yields and changes to labor productivity and trade patterns ([Carleton and Hsiang, 2016](#)). Prices of food, housing, and other goods and services are likely to change as well.

Longitudinal surveys are currently in progress to track economic resilience to climate-related events. The Study of the Tsunami Aftermath and Recovery (STAR) survey follows, over almost 20 years, a large sample of people differentially exposed to the 2004 Indian Ocean Tsunami in Aceh, Indonesia. STAR found that men aged 40-60 were still earning 30 percent less ten years later compared both to their earnings before the tsunami and to the same-aged men who were not exposed to the tsunami. Men aged 20-29 showed more resilience, but nonetheless earned 12 percent less compared to those not directly exposed to the tsunami. Spending levels declined 13 percent in the year following the tsunami, but those directly affected still spend 8 percent less ten years later (while others show a recovery in spending). People adjust and re-optimize in the aftermath of the disaster. In response to the tsunami, women joined the labor force, households started new businesses, and assets were sold, directly decreasing household wealth but probably buffering against the need to sharply reduce spending.

Another ongoing pilot study, Dynamics of Extreme Events, People, and Places (DEEPP), follows individuals in eastern North Carolina who were differentially exposed to Hurricanes Florence (2018) and Dorian (2019). Preliminary results show that inundation of roads and properties outside of hurricanes is becoming more frequent for those living in the coastal plain and salt water intrusion is affecting agriculture. Inundation not only causes expensive property damage, but also significantly disrupts work and daily activities. Many adults have strong ties to place with a limited desire to relocate. Furthermore, mitigation measures can be extremely expensive.

Discussion

Role of Mid-Life in Older Adult Economic Resilience

The financial, social, and human resources with which people enter mid-life likely play a critical role in moderating the effects of climate change on health and economics during old age. Long-duration exposures to housing that is vulnerable to climate impacts are probable in many areas. Future research could focus on the extent to which people recover from large negative climate shocks and/or less severe but more frequent climate events; studies of economic systems could shed light on how climate shocks and more gradual changes in climate affect economic resilience; and researchers could consider the intersection between these dynamics and the

aging process in relation to differential vulnerability. The issues are relevant for flooding, but also for fires, droughts, and temperature change.

Flooding in the Coastal Plain of North Carolina

In North Carolina, flood insurance is required for individuals with mortgages. Rates will likely change soon, but currently they are subsidized for higher value properties at the expense of lower value properties, placing disproportionately increased financial burden and risk on lower-income residents. However, many people in coast areas (which are also very rural) are not affected by the insurance requirement because they inherited their homes without a mortgage or have paid their mortgages in full.

Surveys are useful to better understand the consequences of exposure and attitudes about adaptation and mitigation among residents—especially long-term rather than seasonal residents. Many residents live in unincorporated areas, without a municipality or city to oversee infrastructure planning; in surveys, residents express a recognition of the limitations of that current system but also express strong hesitation about moving away from locations that have always been home. In a similarly conflicted example, many residents express significant anxiety about the long-term feasibility of living in vulnerable areas and report that they would not recommend that their children or grandchildren plan to make their lives there. On the other hand, some people who moved away to pursue economic opportunities elsewhere have returned because of long-standing family ties to place.

Survey-based Research on Climate Change and Health

Compared to the ongoing effects of climate change, extreme events might serve as natural experiments, enabling study of exposed individuals “before” and “after” the event. Surveys can help researchers understand these acute “focal” events while also inquiring about exposure to recurrent or chronic problems that accompany climate change. Surveys can also be very useful when combined with precise, spatially explicit measurements of exposure to different aspects of extreme events (water depth, windspeed, precipitation levels, smoke exposures).

Surveys can also clarify the sub-groups for whom impacts are greatest—possibly older residents for whom evacuation is more complicated in the face of a storm or fire, but also the children and adults whose schooling and work are disrupted. As an example, in one community school buses change hours to avoid regularly flooded roads, which means that particular groups of children miss class much more frequently than their peers.

Longitudinal Studies of Climate Impacts on Health

Longitudinal study designs are especially useful in tracking long-term changes in populations in response to high and low mortality weather events, such as tsunamis and hurricanes, respectively. Tsunamis have high, near-instantaneous mortality while hurricanes show the largest increases in mortality in the year following the event, rather than during the event itself. Posttraumatic stress disorder (PTSD) and other mental health problems, and their impacts on

physiological systems, can take a long time to manifest, underscoring the importance of conducting longitudinal studies of developing health issues.

Longitudinal study design is particularly useful when it combines and integrates other data on exposures and changes to markets and infrastructure. Engineers develop prediction models and monitoring devices that can be combined with data from individuals and households on health and economic outcomes. Survey data on how informal social safety nets operate to buffer against the most negative outcomes of exposures can also shed light on how vulnerable communities protect residents.

Computational Modeling and Projection

Data that supports the estimation of dose-response relationships and behavioral changes in the aftermath of exposures can provide parameters for modelling exercises that project the longer-term evolution of behaviors and outcomes. Such exercises are important given that climate change is already well underway.

Common Mechanisms Across Climate-Related and Other Stress

Some biological and psychological processes that occur in response to stress and trauma operate the same regardless of the source of stress or trauma, whether it be climate-related or from military conflict. In that way, climate events are not necessarily a unique stressor.

Cognitive and Psychological Effects of Climate Change on Older Adults

Noah Webster, Ph. D., Associate Research Scientist, Life Course Development Program, Institute for Social Research, University of Michigan

Urban Flooding

Climate change, coupled with urban development and aging infrastructure, drive greater risks of flooding in many cities nationwide and globally; flooding is not only an issue for coastal and hurricane-prone regions, but also for other regions that experience less severe but more frequent flooding. As a National Academies report noted, “flooding is the natural hazard with the greatest economic and social impact in the United States...” ([National Academies 2019](#)). Flooding is especially dangerous to the financial and medical wellbeing of older adults, who are more vulnerable to flood-related fatalities. Almost half of the deaths from Hurricane Katrina and Superstorm Sandy were among people over the ages of 75 and 65, respectively. Not only are older adults more vulnerable in cases of evacuation, but power disruptions may interrupt use of medical equipment or medication security.

Smart Stormwater Systems

The National Science Foundation (NSF) recently funded the project “[Overcoming Social and Technical Barriers for the Broad Adoption of Smart Stormwater Systems](#),” which used a mail survey to randomly sample residents living in Ann Arbor, MI, Knoxville, TN, and South Bend, IN in 2019. 42.9 percent of respondents were over the age of 60 and 45.9 percent of respondents

lived in a census block group with median annual income below the city median. Survey responses to questions about flood worry found that 36.2 percent of respondents had some level of concern (“worry”) about damage to home/property from standing water caused by rain or snowmelt. Older adults surveyed tended to show less concern about flooding, and this trend was more pronounced among those living in lower income neighborhoods, potentially demonstrating increased resilience.

Green Infrastructure

The University of Michigan led a project titled “Neighborhood, Environment, and Water Collaborations for Green Infrastructure” ([NEW-GI](#)).” The project, funded by the Erb Family Foundation, aimed to assess the efficacy of bioretention rain gardens that manage urban stormwater as a way to address urban flooding. Phase I (2014-2015) of the project involved development of multiple garden designs and construction of four in pilot sites on vacant housing sites and lots in Detroit, MI. Phase II (2016-2018) involved assessment of the operational and social performance of the pilot gardens and development of a plan to bring the designs to scale across the watershed.

Aside from the intended benefits of stormwater management and urban flooding reduction, rain gardens may also add value to the community by reducing the urban heat island effect and air pollution, reducing crime, and providing new opportunities for physical activity, stress reduction/coping, and social interaction. To assess the impact of the pilot gardens and also to explore resident perceptions of multiple garden designs, researchers conducted face-to-face interviews in Detroit’s URT between 2017-2018. 27.3 percent of respondents were over age 60. The survey found no significant difference in flood experience by age, with 36.1 percent of respondents reporting household flooding in the past year. Older adults were more resilient when exposed to flooding compared to younger adults based on self-reported descriptions of flood-related anxiety. Similarly, while statistical analysis revealed a significant correlation between flooding and depressive symptoms among all respondents, this correlation was not statistically significant for respondents over the age of 60, suggesting that older adults were potentially more resilient to the mental health impact of urban flooding. Additionally, older adults benefited significantly more from the rain gardens than younger adults through increased interactions with neighbors.

Risk and Resilience

Climate change can affect psychological health through stress, which can lead to poor mental health and ultimately cognitive decline. Extreme heat, in particular, also leads to an increased risk of illness, hospitalizations, and death, especially among those with chronic conditions and/or limited access to air conditioning (AC). Poor air quality worsens respiratory conditions common in older adults, such as asthma and chronic obstructive pulmonary disorder (COPD).

The effects of climate change on older adults will likely exacerbate life course inequalities and other disparities (e.g., racial/ethnic, SES). However, while most research focuses on climate-

related risks facing older adults, they may also demonstrate resilience in the face of ongoing and future crises, compared to younger adults. Climate change has presented new opportunities for older adults to volunteer and engage in their communities, potentially leading to positive mental health/cognitive outcomes.

Data Needs

While research on older adults is lacking, researchers can leverage existing studies focused on climate change that also collect data on age as a variable and then follow up with older adults in such studies. Ongoing population-level studies would also benefit from including modules assessing experiences and anxiety/distress related to climate change using standardized measures. Larger samples are necessary to analyze within-group heterogeneity among older adults in order to better understand intersections with other factors, such as race/ethnicity and SES. New, especially longitudinal, studies and primary data collections are needed that focus explicitly on older adults and climate change experiences/impacts from a broad range of climate-related events, such as fires and flooding. Longitudinal studies could also be integrated with contemporaneous ecological assessments as flood and climate-related events are occurring.

Discussion

Environmental Benefits to Mental Health

The Detroit rain gardens project underscores an often-overlooked perspective on the environment as beneficial to health rather than only as a threatening source of mortality and morbidity.

Survey-based Research on Climate Change and Health

Public health research into the effects of climate change on health can benefit from longitudinal surveys, provided they account for geographical variation in challenges and negative health impacts. Research efforts using nationally representative samples can miss the people most impacted by climate-related events/conditions, because those groups are small relative to the overall population. To deal with this problem, researchers need to increase sample sizes of surveys and use focused approaches to specific populations and subsets.

The Climate Anxiety Scale (CAS) and the Climate Change Worry Scale (CCWS) are valuable new tools being developed to address climate change and climate-related anxiety. Public health researchers can design and tailor surveys to region-specific concerns using measurements specific to older adults.

The Smart stormwater survey used a larger sample size over three cities, splitting cities into quadrants by median resident income (high vs. low) based on census block data and then overlaying by flood risk (high vs. low) based on data from the Federal Emergency Management

Agency (FEMA). Aging infrastructure, such as storm drainage systems, in lower income regions was associated with increased flooding, not simply proximity to water.

Awareness and Perception of Urban Flooding among Older Adults

In the Smart stormwater survey, questions were designed to assess social awareness of climate and sustainability issues to control for the possibility that a lack of knowledge may have caused lower reported flood concern. Mobility level may influence awareness, because some people with mobility issues may not be aware of basement flooding in their own homes.

Perception of climate issues and incidence of climate-related depression may differ significantly across the life course, which is relevant when researchers attempt to compare older adults to comparable controls. Older individuals may not name flooding as a high priority compared to other life concerns (e.g., financial, medical). In addition, older adults will experience climate change to a much lesser degree than younger adults due to lifespan differences and progressive worsening of climate change over time; thus they may be less concerned or anxious about it.

Panel Discussion

Anne Pebley, Ph.D., Professor, Fielding School of Public Health, University of California Los Angeles (UCLA)

Data Needs

Region-Specific Sampling

Most participants agreed that to apply evidence-based models, public health researchers should collect data that capture place-specific climate interactions and should prioritize data collection in regions/sites with identified climate-related challenges. Stratifying data by ecology and demographic characteristics while allowing for random selection is also important for participant selection.

The National Health and Aging Trends Study (NHATS) uses a Medicare registry to sample older adults and can be combined with overlays of racial and ethnic sampling that may help focus data collection on high-risk areas. Unlike NHATS, other longitudinal studies may follow participants from early to mid-life into residential long-term care (LTC) facilities.

The current data on congregate living facilities and trailer parks is lacking, as is sampling in some key regions (Gulf Coast, New York City), which may reduce the utility of nationally representative data sets. Several participants agreed that larger data sets or location-targeted data sets, possibly through over-sampling of those relevant sites, may provide viable solutions. They also noted that researchers can extrapolate data across regions by analyzing site-specific characteristics that would be generalizable to other, similar sites, and thus reduce the need for distinct surveys on many sites. Partnering with large medical centers to collect participant data enables researchers to make inferences about populations in other similar regions.

Survey Design

Participants all agreed that researchers can supplement current data sets, especially longitudinal data sets, by taking an interdisciplinary approach that engages experts from a variety of relevant fields (e.g., air pollution, environmental change, etc.). The National Academies of Science, Engineering, and Medicine (NASEM) has issued the [Best Practices in Assessing Mortality and Significant Morbidity Following Large-Scale Disasters](#), which could be used to guide surveys to be responsive to climate-related events. However, retrofitting existing data to climate data has significant limitations: existing data may not capture the specific locations and populations that are most affected by extreme climate events, in part because both the events and the extent of their impact are hard to predict and in part because data collection from the most frequently affected populations is limited.

Evidence-Based Theory

Participants all agreed that data measures and surveys should more consistently draw on evidence-based theories. For example, studies that assess resilience to crises/natural disasters often define resilience as recovery to pre-crisis levels, when an evidence-based definition might instead look for a post-crisis *flourishing*. The choice of definition affects what individuals and populations should be surveyed.

Data Enclaves

With appropriate training, researchers can cross-link national survey data in data enclaves (i.e., secure networks containing confidential information) to regional and environmental data. Cross-linking secure enclaves and existing data sets may be administratively easier than launching new studies, as noted by several participants with secure enclave experience.

Limitations Integrating Income Data with Weather Data

Some recent studies have combined data from the Panel Study of Income Dynamics (PSID) with storm event data to explore the financial impact of climate-related weather events, such as hurricanes, on wealth inequality and residential mobility. Statistical power, however, was too weak in one such study aimed at assessing the economic impact of Hurricane Katrina. The Census Bureau does have the ability to link nationally representative income data to specific regions and locations, enabling researchers to create 100 percent samples of specific locations affected by a single event; however, Census Bureau data extraction is difficult due to privacy limitations. Very few health measures can be linked effectively to population measures because most population measures do not directly predict specific negative health outcomes.

Early Warning for Vulnerable At-Risk Communities

FEMA and other federal organizations are developing better national warning systems and risk mitigation systems for vulnerable populations. Early warning systems are difficult to create, because predicting the next climate-related crisis/disaster can be challenging if not impossible. However, these systems could be used to identify communities at risk of exposure to climate

crises and cross reference them with socioeconomically vulnerable populations to ensure that vulnerable communities in high-risk areas are given sufficient warning.

Appendix 1. Meeting Agenda

- 1:00 p.m.** Welcome and Introductions
Anne Pebley, Ph.D., Professor, Fielding School of Public Health, University of California Los Angeles (UCLA)
Emerald Nguyen, Ph.D., Social and Behavioral Science Administrator, Population and Social Processes (PSP) Branch, Division of Behavioral and Social Research (BSR), National Institute on Aging (NIA), National Institutes of Health (NIH).
- 1:20 p.m.** Effects of Extreme Heat, Cold, Weather Events, and Older Adult Housing on Health
Vijay Limaye, Ph.D., Senior Climate Change & Health Scientist, Science Office, Natural Resources Defense Council (NRDC)
- 2:05 p.m.** Effects of Increases in Climate-Sensitive Infectious Disease Prevalence on Older Adults
Ayesha Mahmud, Ph.D., Assistant Professor, Department of Demography, University of California Berkeley
- 2:45 p.m.** Break
- 3:00 p.m.** Impacts of Climate on the Financial Stability and Security of Older Adults
Elizabeth Frankenberg, Ph. D., Professor, University of North Carolina at Chapel Hill, Director, Carolina Population Center
- 3:45 p.m.** Cognitive and Psychological Effects of Climate Change on Older Adults
Noah Webster, Ph. D., Associate Research Scientist, Life Course Development Program, Institute for Social Research, University of Michigan
- 4:30 p.m.** Panel Discussion
Anne Pebley, Ph.D., Professor, Fielding School of Public Health, University of California Los Angeles (UCLA)
- 5:00 p.m.** Adjourn

Appendix 2. List of Participants

Presenters

Elizabeth Frankenberg, University of North Carolina at Chapel Hill
Vijay Limaye, Natural Resources Defense Council (NRDC)
Ayesha Mahmud, University of California Berkeley
Noah Webster, University of Michigan

CPOP Members

Emily Agree, Johns Hopkins University
Deborah Balk, Baruch College of the City University of New York
Ann Blanc, Social and Behavioral Science Research, The Population Council
Courtney Coile, Wellesley College
Sonalde Desai, University of Maryland
Dana Glei, Georgetown University
Robert Hummer, University of North Carolina at Chapel Hill
Hedwig (Hedy) Lee, Washington University in St. Louis
Jennifer Manly, Columbia University
Jenna Nobles, University of Wisconsin-Madison
Anne Pebley, University of California Los Angeles
Fernando Riosmena, University of Colorado Boulder
David Takeuchi, University of Washington

CPOP Staff

Tara Becker, Program Officer
Alex Henderson, Senior Program Assistant
Rebecca Krone, Program Coordinator
Malay Majmundar, Director

National Institute on Aging

Jessica Boten, Social Science Analyst, BSR
Minki Chatterji, Program Official, Population and Social Processes Branch, BSR
Elena Fazio, Program Official, Population and Social Processes Branch
Amelia Karraker, Program Official, Population and Social Processes Branch, BSR
Theresa Kim, Program Official, Population and Social Processes Branch, BSR
Charlie Le, Social Science Analyst, Population and Social Processes Branch, BSR
Liz Necka, Program Official, Individual Behavior Processes Branch, BSR
Lis Nielsen, Division Director, BSR
Emerald Nguyen, Social and Behavioral Science Administrator, BSR
John Phillips, Branch Chief, Population and Social Processes Branch, BSR

Guests

Regina Bures
Elizabeth Fussell

Eric Grimes
Amanda Sonnega
Noah Webster

Rose Li & Associates, Inc. (Contractor)

Tomas Pitfield, Science Writer