George Perkins Marsh Institute Highlights, Accomplishments, and Impacts

Annual Report 2020-2021

# Promoting Sustainable Environments for the Public Good

# Informing Solutions to Global Change

#### **On the Front Cover:**

Hadwen Arboretum in Worcester, Massachusetts. Students working with Marsh Institute researcher John Rogan (Professor of Geography) are gaining on-the-ground experience in forest managememt practices by engaging in revitalization activities such as tree tagging, brush removal, new tree plantings, new trail development, and visitor signage improvement.



The George Perkins Marsh Institute at Clark University is dedicated to research on one of the most fundamental questions confronting humankind:

#### How Can We Sustain Natural and Human Systems Amidst Profound Global Change?

Human actions are causing profound transformations of integrated systems at unprecedented speeds and scales. Through complex feedback processes, these changes pose direct threats to the sustainability of natural and social systems, and lead to deep uncertainties for decision-making. The institute promotes collaborative, evidence-based research that challenges traditional disciplinary boundaries to address some of the most pressing issues facing today's world.

Work at the Marsh Institute is oriented around an understanding of global environmental change and how we can safeguard the natural and social systems that support human livelihoods. Our primary research themes include (1) Climate Change Impacts and Adaptation, (2) Local and Global Food Security, (3) Healthy and Viable Ecosystems, and (4) Sustainable Communities and Livelihoods, with an important focus on risk, vulnerability, mitigation, and adaptation.

The Marsh Institute is one of the most productive hubs for research and funding at Clark University, regularly generating approximately half of all external research funds received by the university. Our work solves real-world problems and engages with partners from individual households to organizations and agencies working at national or global scales. External support for these and other institute activities comes from federal, state, local and international grants, private donations, foundations, and other sources.

The Marsh Institute is also dedicated to the provision of research opportunities for Clark undergraduate and graduate students. Dozens of students participate in the institute's research projects. Other programs focused on student research include the Human-Environment Regional Observatory (HERO) research program and the Albert, Norma and Howard '77 Geller Student Research Grants.

The Marsh Institute makes a difference through advancements in basic and applied science, engagement with decision-makers, and communication with the public. We develop new ways to study, understand and model socio-ecological systems from local to global scales. We work directly with decision-makers to inform policy. We coordinate workshops, conferences, and seminars that bring together scientists, students, stakeholders, and policy makers. We also host visiting scientists to promote cross-institutional collaborations. Institute researchers play important roles in national and international science and policy advisory bodies. The institute also represents Clark University in its role as a recognized non-governmental observer organization with the United Nations Framework Convention on Climate Change (UNFCCC).

Among the facilities, offices, and centers that comprise the Marsh Institute is the Jeanne X. Kasperson Research Library, whose holdings include one of the most extensive research collections in North America on risks, hazards, and global environmental change. We are also home to the Humanitarian Response and Development Lab (HURDL), the Center for the Study of Natural Resource Extraction and Society, and the new Blackstone Watershed Collaborative. We work closely with departments and schools across Clark University, including the Graduate School of Geography, the Department of International Development, Community, and Environment, the Department of Economics, and Clark Labs.

This annual report highlights some of the recent areas in which the George Perkins Marsh Institute is making a difference through environmental research, engagement, education, outreach, and communication.

Robert J. Johnston, Director

### **GRANTS AND REVENUES**

A large portion of Clark University's external grant funding is generated by the Marsh Institute, in coordination with our partners in the Graduate School of Geography, the International Development, Community, and Environment Department, and the Department of Economics, among others. This past year, the institute maintained approximately \$10.8 million in current grants, covering 32 active projects: 13 grants for small (under \$100,000) projects, 16 grants for medium (\$100,000 - \$500,000) projects, and 3 for large (over \$500,000) projects. Eight grants are components of large-scale, multiinstitutional research projects, each exceeding \$1 million in total funding. During FY2021, the institute was awarded \$1,261,345 million in new grants, with an average size of \$126,135 per grant. The institute's overall proposal success rate was around 30%, with higher success rates for small (54%) and medium (33%) grants.







Broken down by research theme, projects related to food security concerns represent 37% of total grant funds, although many of those projects also address climate and global change. Projects related to healthy ecosystems provide another 31% of grant funds. The largest number of projects are related to sustainable communities.



Research at the Marsh Institute addresses some of the most critical issues facing society today. Research topics fall under one or more broad themes related to sustainable natural and human systems: (1) Climate Change Impacts and Adaptation, (2) Local and Global Food Security, (3) Healthy and Viable Ecosystems, and (4) Sustainable Communities and Livelihoods. Much of the research at the institute is interdisciplinary in nature,

and conducted in large teams with collaborations among Clark researchers as well as with researchers at other institutions around the world. Individual projects may focus on the advancement of new theories, the development of new tools and methodological approaches, the application of existing tools to specific case studies, or the analysis of policies and programs that impact the health and well-being of integrated human and natural systems. The scale of projects ranges from single natural resources to local neighborhoods to regional watersheds to whole countries and the entire globe. New research projects initiated during 2021 address topics such as: revitalizing urban parks and neighborhoods, improving delivery of farm extension services in Africa, assessing climate mitigation opportunities in North America, advancing models of spatially-explicit ecosystem service benefits, developing accurate land cover maps, understanding Latinx families' experience with telehealth, improving climate forecasting and knowledge exchange in the state of Hawai'i, and developing collaborative stakeholder networks to ensure healthy and resilient watersheds.

# RESEARCH PROJECTS

### CLIMATE CHANGE IMPACTS AND ADAPTATION

Global climate change affects every living organism on the planet through cascading effects such as an increased intensity and frequency of droughts, floods, forest fires, pest infestations, and habitat destruction and degradation. Marsh Institute researchers are at the forefront of science and policy efforts to inform climate change mitigation, adaptation, and long-term resilience to sustain ecological systems and human livelihoods. For example, Abby Frazier is collaborating with researchers across the state of Hawai'i to share knowledge and data regarding local and regional drought situations to inform stakeholder actions and policy decisions. Karen Frey is quantifying the impact of thinning and retreating sea ice on biological productivity and biogeochemical cycling in the Arctic. Robert (Gil) Pontius is exploring how internal feedbacks within the Gulf of Maine marsh-estuary ecosystem influence resilience and responses to climate change, sea-level rise, and urbanization of the watershed. Christopher Williams is developing decision-support tools for evaluating climate change mitigation opportunities from reforestation, avoided deforestation, and improved forest management. Williams is also investigating the uncertainty in current models of carbon dioxide and methane sources and sinks to produce more accurate predictions of a future climate and improve climate change mitigation and adaptation. Deborah Woodcock is

examining plant-based fossil records in northeastern Peru to understand historically warm climate conditions and resulting biogeophysical ramifications that may offer insights for future climate scenarios. Through these and other projects, Marsh Institute researchers are helping to ensure sustainable natural and human systems in a world threatened by a rapidly changing global climate.



#### Routine Monitoring of Climate in the State of Hawai'i: Establishment of State Climate Divisions

Principal Investigator: Abby Frazier Funding Agency: National Weather Service (NWS)

Basic climate summaries and historical climate analyses produced by the National Centers for Environmental Information (NCEI) do not include the state of Hawai'i, largely because Hawai'i is the only state that does not have assigned climate divisions. This project will develop the analytical approach to produce climate divisions for Hawai'i with regional groupings analogous to the contiguous United States' climate division records. Rainfall in Hawai'i exhibits a number of extremes that include some of the wettest locations on earth, and short-term extreme events that rival national extreme values. Extreme drought events also regularly affect the state. Given the strong spatial climate gradients in Hawai'i, careful analysis is needed to develop appropriate climate regions that characterize the state's spatial and temporal variability. This information is required to better understand climate variability and change, and to include Hawai'i within NCEI's suite of state and national climate products. The production of climate divisions for Hawai'i will support development of a robust monitoring and forecasting framework, enhancing seasonal forecasting at NWS and monitoring through NCEI.

#### Scaling up the Hawaiʻi Drought Knowledge Exchange

Principal Investigator: Abby Frazier Funding Agency: U.S. Forest Service

Collaborations among scientists and managers is needed to effectively address drought in Hawai'i. The Pacific Islands Climate Adaptation Science Center's Hawai'i Drought Knowledge Exchange (HDKE) project piloted three sets of formal collaborative knowledge exchange between researchers and managers to co-produce customized, site specific drought data products to meet the needs of each partner. This project will expand the HDKE project to include additional stakeholders and collaborations to meet the needs of a larger number of resource managers across the state. Objectives include: (1) streamlining the process of drought knowledge coproduction and exchange to support an expanded group of stakeholders; (2) continuing to demonstrate good aspects of a knowledge exchange (e.g., easier access to drought and climate information and data sources; better and more comprehensive information; improved technical assistance; and more collaborative information transfer); and (3) co-produce site-specific climate syntheses. This project will improve the capacity of managers to learn from each other in planning for climate change, variability, and drought.



#### The Distributed Biological Observatory (DBO) — A Change Detection Array in the Pacific Arctic Region, 2019-2024

Principal Investigator: Karen Frey Funding Agency: National Science Foundation

The Pacific Arctic Region (PAR) is experiencing major reductions in seasonal sea ice and increases in seawater temperatures. A key uncertainty is how the marine ecosystem will respond to these shifts. Recent observations indicate these changes are linked to shifts in species composition and abundance, as well as northward range expansions in higher trophic predators (e.g. gray and humpback whales, and commercially harvested fish). There is also evidence of negative impacts on ice-dependent species such as walruses. Some distribution shifts may be driven by changes in lower trophic level productivity that cascade into higher trophic levels. Spatial changes in carbon production and export to the sediments are additional observations that have grown out of recent sampling efforts. An international consortium of scientists has implemented a coordinated Distributed Biological Observatory (DBO) that undertakes selected biological measurements at multiple trophic levels, simultaneously collected with hydrographic surveys (salinity, temperature, and nutrients) and satellite observations. The DBO approach provides multiple repeat sampling each year and new, more seasonally continuous data on the status and developing trends for the PAR ecosystem. This continuing project will address questions such as: (1) Will earlier sea ice retreat and changes in seawater hydrographic properties influence the composition of pelagic and benthic prey species, and how will upper trophic organisms be affected? (2) What is the impact of seasonal changes in hydrography on the lateral and vertical distribution of primary production and export production to the benthos? (3) What will be the ecosystem responses to latitudinal changes in environmental drivers and can we forecast the biological response to components of the food web through ecological modeling?



#### LTER/PIE: Dynamics of Coastal Ecosystems in a Region of Rapid Climate Change, Sea-level Rise, and Human Impacts

Principal Investigator: Robert Gilmore Pontius Jr. Funding Agency: National Science Foundation

Over the last 30 years, surface seawater temperatures in the Gulf of Maine have risen at three times the global average, rates of sea-level rise have accelerated, and precipitation has increased. Coupled with these changes in climate and sea level are substantial changes within the rapidly urbanizing watersheds that influence water, sediment, and nutrient delivery to marshes and estuaries. The Plum Island Ecosystems (PIE) Long Term Ecological Research (LTER) site is developing a predictive understanding of the response of a linked watershedmarsh-estuarine system in northeastern Massachusetts to rapid environmental change. This large-scale, interdisciplinary project tests how internal feedbacks within the marsh-estuary ecosystem influence the response of geomorphology, biogeochemistry, and food webs to three major drivers: climate, sea-level rise, and human alteration of the watershed. It will address three critical questions. (1) How will the geomorphic configuration of the marsh and estuary be altered by changes in the watershed, sea-level, climate, and feedbacks internal to the coastal system? (2) How will changing climate, watershed inputs, and marsh geomorphology interact to alter marsh and estuarine primary production, organic matter storage, and nutrient cycling? (3) How will key consumer dynamics and estuarine food webs be reshaped by changing environmental drivers, marshestuarine geomorphology and biogeochemistry? Crosssystem comparisons with other LTERs along gradients of temperature, species composition, tidal range, and sediment supply will further our understanding of longterm change in coastal ecosystems.

### Applied Science to Catalyze Natural Climate Solutions

Principal Investigator: Christopher A. Williams Funding Agency: The Nature Conservancy and The Bezos Earth Fund

Climate change is a global problem that will require both reductions in new greenhouse gas emissions and removal of existing gases from the atmosphere. This project's aim is to provide the data and decision-support tools needed to quantify the albedo component of assessments evaluating climate change mitigation opportunities from reforestation, avoided deforestation, and forest management. The project draws upon on prior research in the U.S. and Canada, refining the methods to expand the analysis to a global scale. The research will sample a global atlas of satellite-derived surface albedos defined for specific land cover types, combine these with climatology data on snow cover, solar radiation, and radiative kernels to compute the global scale radiative forcing that would result from forest cover conversions representative of deforestation and reforestation opportunities in a given area, and relate these radiative forcings in terms of global warming potential. Datasets will be delivered to The Nature Conservancy for integration into products, tools, and/or web platforms, and the project team will aid in integration and associated communications. Scientific findings will inform the identification of areas of opportunity where changes in forest cover or forest composition are expected to yield net climate benefits.

#### Bringing Forest Carbon into Focus: Improved Estimates of Carbon Benefits from Avoided Forest Conversion in New England and New York

Principal Investigator: Christopher A. Williams Funding Agency: U.S. Climate Alliance and The Nature Conservancy

Climate change is a global problem and limiting global warming below the 2°C threshold set by the Paris Climate Agreement will require both reductions in new greenhouse gas emissions and removal of existing gases from the atmosphere. Natural Climate Solutions (NCS) is a portfolio of conservation, restoration, and improved land management actions that increase carbon storage or avoid greenhouse gas emissions across forests, wetlands, grasslands, and agricultural lands. This project's aim is to assess the climate change mitigation potential of NCS opportunities in the northeastern U.S. The work will refine and tailor methods developed in previous studies, including more detailed and quantitative assessment of the albedo-induced radiative forcing and associated CO2 equivalent emissions that would be caused by the avoidance of forest conversion, by expanded forest cover (afforestation), or by actively increasing the deciduous component of forest species composition in select regions of New England and New York.

#### Tools to Bridge the Gap between Static CMS Maps, Models, and Stakeholders

Principal Investigator: Christopher A. Williams Funding Agency: National Aeronautics and Space Administration

From its inception, the NASA Carbon Monitoring System (CMS) has been largely organized around two activities: observation-based mapping of biomass and modelbased estimation of carbon flux. Although there has been significant progress in both biomass and flux activities at various scales, several challenges hinder the use of biomass products to inform flux modeling. For example, biomass maps are often static or local scale, uncertainties are difficult to render and incorporate into models, and map products are not designed with the needs and format standards of modelers in mind. To help address these challenges, this project will develop new tools to facilitate broader use of CMS data products by (a) converting static maps of aboveground biomass and land cover to dynamic yearly maps, and (b) collaborating with modelers and stakeholders to build a convenient interface that will facilitate their use of the dynamic map results. This will add significant value to the CMS program by thoughtfully and deliberately connecting the results from various disparate projects to each other and to modeling and accounting frameworks that provide a more integrated view of carbon dynamics.

#### Surface Biogenic Carbon Flux Priors: Providing Priors, Analyzing Error Structures, and Reducing Parameter Uncertainties

Principal Investigator: Christopher A. Williams Funding Agency: National Aeronautics and Space Administration

Better estimates of greenhouse gas sources and sinks are needed for climate management and to predict future climate. Atmospheric Carbon and Transport–America conducts airborne campaigns across three regions in the eastern United States to study the transport and fluxes of atmospheric carbon dioxide and methane, and to measure how weather systems transport these greenhouse gases with the overall objective of enabling more accurate and precise estimates of the sources and sinks of these gases. Biogenic surface carbon flux prior estimates are a necessary component of the regional atmospheric inversion framework utilizing aircraft data. This project delivers surface carbon flux priors to support regional inversions centered on aircraft campaigns and analyzes prior and posterior surface carbon fluxes to identify a reduced set of model parameters that are most consistent with the aircraft data.

#### What Can a 39-million-year-old Coastal Ecosystem Tell Us about Climate and Earth History?

Principal Investigator: Deborah Woodcock Funding Agency: National Geographic Society

Mangrove ecosystems are rarely represented in the fossil record because the dynamic nature of the coastal environment is not conducive to the preservation of organic remains or shelly material. The Piedra Chamana Fossil Forest in northern Peru was preserved 39 million years ago when a volcanic eruption buried coastal mangroves and nearby forests in volcaniclastic deposits. The unusual circumstances of preservation underscore the potential of the site to provide a multi-proxy record that will: (1) provide a uniquely detailed picture of late middle Eocene mangrove and lowland tropical forest ecosystems; (2) contribute to our understanding of the history of the New World tropical forests and development of tropical biodiversity; (3) allow for comparison and evaluation of paleoenvironmental proxies (leaves versus woods, marine versus terrestrial, geochemical versus biological) that do not generally cooccur; and (4) serve as a rich baseline reference of the vegetation and environment in the New World tropics at a time of considerable global warmth. The project also supports interpretation and education efforts related to conservation and protection of the fossils and fossil site.



### LOCAL AND GLOBAL FOOD SECURITY

Population growth, shifting consumption, regional conflicts, degradation of ecosystem services, natural hazards, and a changing climate are among the factors that threaten food security across the globe. Marsh Institute researchers are at the forefront of efforts to help ensure food security worldwide. These threats are particularly severe in the developing world. For example, Lyndon Estes' interdisciplinary and multi-institutional collaborative work investigates the drivers and impacts of agricultural change, with a particular focus on sub-Saharan Africa. His recent work includes the use of satellite imagery and ground-truthing to accurately map the location of cropland and particular crops in order to facilitate agricultural extension services, the characterization of agricultural production and associated land use change under different urbanization scenarios, and the development of sensor networks to understand changing rainfall patterns and relationships to farmers' planting and harvesting decisions. Food insecurity can also occur in developed countries, although the challenges may be different. For example, **Robert Johnston** is investigating how the public perceives northeast U.S. shellfish aquaculture, and how new operations can be developed in ways that maximize public support. Other types of threats to food security result from the

agricultural use of pesticides and other chemicals, with acute and chronic effects on agro-ecosystem services. For example, **Dana Bauer** is working with multi-disciplinary teams to evaluate the biophysical and socio-economic conflicts and tradeoffs among pest management and pollination services in U.S. agriculture. Through these and other projects, Marsh Institute researchers are helping to ensure the resilience of agricultural systems upon which societies depend.



#### Informing Conservation Program Targeting for Cost-Effective Integrated Pollinator-Pest Management

Principal Investigator: Dana Marie Bauer Funding Agency: U.S. Department of Agriculture

Recent declines in both managed and wild pollinators have been attributed in part to habitat loss and pesticide exposure. Thus, growers of pollinator-dependent crops are confronted with potential on-farm tradeoffs between effective pest control and successful pollination. However, growers differ in their knowledge of the impacts of pesticide exposure on pollination services and differ in their willingness to adjust management practices to address these impacts. These differences likely depend on the particular cropscape within which the grower operates. This project will first develop an integrated pollinator-pesticide cropscape typology that places each county in the continental U.S. along a pollinator riskreward gradient. The research will then conduct grower surveys in select cropscapes to answer the following questions: (1) How aware are growers of the different pathways through which pollinators are exposed to pesticides? (2) Will provisioning of information regarding the damages of pesticides and the benefits of pollinator habitat offer enough private incentive for growers to change their management practices or are additional policies or programs, such as payments for habitat conservation, warranted? (3) How do differences among growers and cropscapes vary across the U.S. and how can we use this information to guide cost-effective spatial targeting of federal, state, and local pollinator conservation programs?

#### Navigating the Tradeoff between Pest Management and Pollinator Conservation

Principal Investigator: Dana Marie Bauer Funding Agency: U.S. Department of Agriculture

Neonicotinoid insecticides ('neonics') experienced an exponential rise in use on farmland over the past two decades and are now the most widely used insecticides in the world. The attributes that make neonics versatile and powerful pest management tools also make nontargeted insects vulnerable to their effects. Specifically, neonics have been implicated as a factor in sudden dieoffs of managed honeybees and long term declines in native bee populations. Thus, farmers growing pollinatordependent crops, which represent a large fraction of all fruits and vegetables, are confronted with a potential trade-off between two competing aspects of crop production: effective pest suppression and successful pollination. The overarching goal of this project is to develop holistic pest-pollinator joint management regimes that are effective, profitable, and sustainable. The project will: identify insecticide management strategies that simultaneously optimize pest suppression while minimizing

non-target exposure to pollinators; determine the consequences of neonic exposure for honeybee and wild bee health; and assess the ecological and socioeconomic trade-offs among pollinators, pests, crop yield, and farm profitability resulting from alternative pest management regimes. This interdisciplinary research partnership involves collaborators from Purdue University, Michigan State University, Ohio State University, and the University of New Hampshire. Marsh Institute researchers are leading the economic analysis of grower decision making.

#### Creating Open Agricultural Maps and Ground Truth Data to Better Deliver Farm Extension Services

Principal Investigator: Lyndon Estes Funding Agency: Gates Foundation and Farmerline

Smallholders in Africa often lack access to inputs and information that can help boost their productivity and resilience to major sources of volatility including climate shocks. One key reason for this inadequacy of agricultural extension services is the absence of data that accurately map where croplands are and what crops are grown. Making such maps is challenging because it requires the ability to use satellite imagery to accurately map the boundaries of smallholders' fields over large areas, and the ability to collect, on an annual basis, precisely geo-referenced ground-truth observations that detail which crops are growing within a large sample of those mapped field boundaries. This project will generate ground-truth data and accurate maps of croplands that will allow provisioning of new agricultural extension services to farmers.





#### Developing and Scaling Up the Mapping Africa Active Learning Platform

Principal Investigator: Lyndon Estes Funding Agency: Omidyar Network

The need for both growth and reform of agriculture is particularly urgent in sub-Saharan Africa (SSA), where populations are expected to double and economies quintuple by 2050, leading to a tripling of food demand. Existing agricultural maps for SSA fail to quantify even the most basic agricultural characteristics (where and how much cropland there is), and must become more accurate at finer resolutions if we are to adequately solve agriculture's challenges. This project refines and tests a methodology for a scalable, fast, and cost-effective land cover mapping platform based on a next generation machine-learning algorithm that directs human mappers (based in SSA) to collect training data over the most difficult to classify locations. Active learning produces maps that are more accurate across a broader range of agricultural types than conventional classification methods. The maps will not only distinguish agricultural from non-agricultural areas with unprecedented accuracy, but will go beyond pixel-based classifications to map individual fields. The platform will be tested in Ghana.

#### Impacts of Agricultural Decision Making and Adaptive Management on Food Security

Principal Investigator: Lyndon Estes Funding Agency: National Science Foundation

Despite significant attention from governments, donor agencies, and NGOs, food security remains an unresolved challenge in the context of global human welfare. Technical and conceptual limits have prevented the collection and analysis of rich empirical datasets with high temporal frequency over large spatial extents necessary to investigate how changes to seasonal precipitation patterns affect food security. Working with collaborators at UC Santa Barbara and University of Arizona, this project will integrate physical models of hydrological and agricultural dynamics with realtime environmental data obtained from cellular-based environmental sensing pods and real-time reports of farmer decision making submitted via cell phones. The research addresses three critical questions: (1) How do intra-seasonal dynamics of the environment and social systems shape farmer adaptive capacity? (2) To what extent does intra-seasonal decision making enable farmers to adapt to climate uncertainty? (3) How can intra-seasonal data improve the ability to model, predict, and improve adaptation to climate variability in ways that enhance food security?

#### Integrating Crowdsourcing, in situ Sensing, and Spaceborne Observation to Understand the Sustainability of Smallholder Agriculture in African Wet Savannas

Principal Investigator: Lyndon Estes Funding Agency: National Aeronautics and Space Administration

Livelihoods in sub-Saharan Africa (SSA) rely heavily on small-scale farming. This dependence could deepen as SSA's wetter savannas will be increasingly farmed to meet growing food demand, while economic growth strategies promote the expansion of smallholder farming. This agricultural development in a region with a highly variable climate raises two important sustainability questions: (1) Do strategies for increasing smallholders' productivity increase or decrease their resilience to climatic variability? (2) Will productivity gains minimize the amount of new land needed for agriculture? This project uses a novel approach that integrates crowdsourcing, in situ environmental sensing, and earth observing satellites to achieve three main objectives: (1) identify patterns of cropland change; (2) identify landscape-scale trends in smallholder productivity; and (3) understand the relationships among changes in crop productivity, land cover, and climatic variability. The project focuses on maize farming in Zambia.

#### Linkages and Interactions between Urban Food Security and Rural Agricultural Systems

Principal Investigator: Lyndon Estes Funding Agency: National Science Foundation

Meeting urban food demand due to population growth, the changing nature of food consumption patterns, and the vulnerability of both local and regional food production to environmental variability present future challenges. Globalization and international trade of food and commodities are key aspects of how urban areas will meet future food demand. But urban areas exhibit different levels of connectivity to international, regional, and local food systems. Additionally, most urban food security research has focused on large metropolitan areas, despite the reality that significant numbers of urban residents live in small to moderate sized urban places. Given complex patterns of urbanization and their differential engagement with global, regional, and local food supply chains, new research is needed to understand what types of urban places are most vulnerable to impacts of local and regional crop production, and what type of urban agglomerations can mitigate those impacts through food imports from distant areas. This project evaluates the impacts of environmental variability on rural agricultural production and how this affects urban food security, and, in turn, how urban population growth affects the demand for local and regional agricultural production, as measured through food trade and other flows. This large-scale interdisciplinary research partnership involves collaborators from University of Arizona, University of California Santa Barbara, and University of Illinois at Urbana-Champaign. Marsh Institute researchers are responsible for characterizing rural agricultural production using remote sensing, and modeling the land use impact of different urbanization scenarios.

#### Understanding Cross-scale Interactions of Trade and Food Policy to Improve Resilience to Drought Risk

Principal Investigator: Lyndon Estes Funding Agency: National Science Foundation

Food security in regions affected by drought is influenced by a complex set of interactions among hydrological, agricultural, and social systems. Previous models examining the impact of drought on food security have not incorporated food trade and food movements at fine spatial scales, yet these components are critical parts of regional food systems. In sub-Saharan Africa, droughts and floods account for approximately 80% of fatalities and 70% of the economic losses that are due to natural hazards. This project's goal is to understand the effect of drought hazards in subsistence agriculture, using an integrative framework that merges data, models, and knowledge of drought risk and crop production, their interactions with the dynamics of trade-based and aidbased responses, and their effect on household food security and consumption. With collaborators at Princeton University, the project addresses three questions: (1) What are the spatio-temporal scales of drought risk across Zambia and how does risk transfer into agricultural impacts? (2) What is the role of trade and domestic food policy on food security at local to national levels? (3) Can drought impacts be more effectively reduced by integrating an understanding of policy and food transfers into an agricultural drought early warning system?

#### Advancing Southern New England Shellfish Aquaculture through an Engaged Public and Next Generation Tools

Principal Investigators: Robert J. Johnston and Dana Marie Bauer Funding Agency: NOAA, National Sea Grant

The largest sector of the U.S. marine aquaculture industry is molluscan shellfish (e.g., oysters, clams and mussels), which accounts for more than 50% of total production. A large number of shellfish operations are concentrated within Connecticut, Rhode Island and Massachusetts, where significant growth potential exists and in which stakeholder-based efforts are being implemented to support and expand this important U.S. food production sector. One of the challenges facing future growth of the shellfish aquaculture industry in this region is siting aquaculture operations in the face of negative public perceptions and concerns highlighted by the media about environmental impacts and human use conflicts. Although in some cases these perceptions may be grounded in personal experience or accurate information, in other cases they may be motivated by a misunderstanding of the science or a past inability of aquaculture stakeholders to speak to the concerns relevant to the public. This project will examine public values and support for prospective shellfish aquaculture expansion programs that could be enacted region- or state-wide, as determined by alternative development strategies. The analysis will also consider the systematic effect of different types of information on this support, and how values and perceptions differ across resident groups. The purpose is to characterize how state and regional efforts to promote shellfish aquaculture can be designed and communicated in ways that best match residents' preferences-and hence optimize public support and value.

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### HEALTHY AND VIABLE ECOSYSTEMS

Healthy and productive ecosystems, and the plethora of services they provide, are crucial for sustaining human well-being. Ecosystem services include provisioning of food, water, fiber, energy, and medicines, purification of air and water, and protection from natural hazards. However, many ecosystems across the globe are being threatened by anthropogenic activities including overuse of natural resources, conversion of natural land covers to impervious surfaces, and inadequate waste disposal. Marsh Institute researchers are at the forefront of science and policy efforts to manage and protect ecosystems and the ecosystem services they provide. For example, **Robert Johnston** is working with an international team to understand the damages caused by marine plastic pollution and identify the benefits that can accrue from international coordination and cooperation. Johnston is also investigating the widespread concern of nitrogen runoff from residential lawns in urban and suburban landscapes, and developing state-of-the-art techniques for quantifying the economic benefits of spatially-explicit ecosystem services. **Lyndon Estes** is using optical imagery to characterize changing forested landscapes in order to facilitate land tenure management and the design of conservation policies. **Robert (Gil) Pontius** 

is collaborating on a large-scale effort to develop detailed time-series land cover change maps

of Brazil that will support sustainable management and conservation of natural resources. **Christopher Williams** is testing whether prime hardwood forest clearing rates near wood pellet mills in the mid-Atlantic U.S. has increased beyond long-term sustainable harvests and at rates that endanger valuable wildlife habitat. Through these and other projects, Marsh Institute researchers are helping to maintain healthy ecosystems and conserve the supply of critical ecosystem services.



#### Unlocking the Power of Active Remote Sensing for Ecosystem Services Modeling in the Amazon's Forest-Agriculture Interface

Principal Investigator: Lyndon Estes Funding Agency: NASA, Jet Propulsion Laboratory

The last decade has experienced a dramatic improvement in the extent and consistency of tree cover and gross deforestation products from optical imagery. These optical-based datasets are capable of tracing forest clearings made for plantations and pastures, but they suffer from cloud cover and may lump mature forest, secondary forest, and plantations into a single 'forest' class. This project augments existing deforestation monitoring systems by filling two important knowledge gaps: (1) characterization of landscapes beyond binary forest versus non-forest classification – required in order to strategize zoning, monitoring, and enforcement; and (2) identification of the commodities that potentially replace forest stand once deforestation is detected. The project will: (1) expand land cover maps by identifying oil palm and cacao plantations and secondary forests; (2) develop a prototype tool that utilizes plantation maps to assess compliance by farmers enrolled in Zero Deforestation Supply Chain initiatives; and (3) transfer knowledge and technology to end-users while addressing locally-relevant questions.

#### The Economics of Marine Plastic Pollution: What are the Benefits of International Cooperation?

Principal Investigator: Robert J. Johnston Funding Agency: Economic and Social Research Council (UK)

Plastic pollution is a global phenomenon with significant impacts on the marine and coastal environment. The physical properties and uncertainties associated with marine plastic, combined with the transboundary nature of the problem and a lack of international markets for control, has led to a lack of effective global actions to address the challenge despite increasing worldwide recognition of the problem. The aim of this international research project is to provide new insights on the economic damages associated with global marine plastic, the costs of reducing this pollution problem, and the net benefits of international coordination. The project, involving collaborators from University of Stirling, University of Glasgow, and Plymouth Marine Laboratory, is organized around four research questions, focused on a case study area in the North Atlantic: (1) What is the probable spatial distribution and movement of marine plastic and what are the associated ecological impacts? (2) What are the economic damage costs associated with marine plastic, for a range of North Atlantic countries? (3) What are the costs of reducing both the stock and the flows of plastic into and within the marine environment of the North Atlantic? (4) What are the economic benefits of

different levels of international cooperation in emissions reductions, and what does this imply about incentives to cooperate?

#### Eliciting and Modeling Residential Lawn and Landscape Practices: Systematic Information to Assess Knowledge, Explicit Behavior, and Inform Management across the Long Island Sound Watershed

Principal Investigator: Robert J. Johnston Funding Agency: NOAA, National Sea Grant

There is significant concern about the environmental impact of residential lawns, especially the extent to which they export nutrients and how this export is related to human behavior such as lawn fertilizer use. Despite past research seeking to characterize residential lawn care, there is no clear understanding of the most effective means to influence lawn care practices across the Long Island Sound watershed. Past research has focused on general attitudes and socio-economic factors associated with residential land management, including behaviors such as fertilizing, irrigating and mowing. However, this literature has been unable to inform plans that are effective at influencing lawn care practices, because it has not produced a satisfactory explanation for the variation in practices that influence nitrogen export and stormwater runoff, or evaluated the extent to which specific programs or policies can influence these practices moving forward. Hence, lawn care and its impacts remain an unresolved challenge emphasized by Long Island Sound strategic planning. This interdisciplinary research project, with collaborators from City University of New York and Florida Atlantic University, will adapt and extend existing integrated models, experimental designs, and survey instruments to model the dynamics of lawn care behaviors across the Long Island Sound watershed.



#### Estimation of Spatially Explicit Water Quality Benefits throughout River Systems: Development of Next Generation Stated Preference Methods

Principal Investigator: Robert J. Johnston Funding Agency: U.S. Environmental Protection Agency

Stated Preference (SP) methods are survey-based approaches to calculate the economic value of environmental improvements, and provide the only means to measure total use and nonuse willingness to pay (WTP) for water quality change. Yet water quality has multiple characteristics that pose challenges for WTP estimation: water quality can vary spatially and temporally; the role of small streams is often under-appreciated; and water quality benefits are often realized through direct and indirect effects on other ecosystem services valued by different user and nonuser groups. This large, interdisciplinary project will develop and evaluate a nextgeneration approach to SP valuation, Free-form Choice Experiments (FCEs). FCEs restructure the way that WTP is elicited and estimated. The approach can estimate use and nonuse WTP for linked water quality and ecosystem service improvements across river networks. The project advances the methods used by government agencies and others to calculate the benefit of water quality improvements to society. The project is led by Marsh Institute director Robert Johnston, with collaborators from the University of New Hampshire, Virginia Technological Institute, and Abt Associates.

#### Targeted Conservation Contracts to Enhance Agricultural Best Management Practices

Principal Investigator: Robert J. Johnston Funding Agency: U.S. Department of Agriculture

This interdisciplinary project is a partnership between economists at the Marsh Institute and both economists and agronomists at the University of Delaware and Auburn University. The United States spends billions on state and federal policies encouraging farmers to implement best management practices (BMPs) through conservation contracts. BMP programs seek agricultural objectives, such as increasing crop prices by reducing production, and environmental objectives, such as providing wildlife habitat. Yet existing research provides little insight on the design of more flexible BMP contracts that capitalize on farmer differences and desires to enhance costefficiency and agri-environmental outcomes. The goal of this project is to improve the cost effectiveness of policies used to promote BMPs on farms in the U.S. The research will inform the development of targeted, costeffective conservation contracts that can be used by governmental agencies to incentivize agricultural BMPs, focusing on programs that encourage the use of cover crops. It will produce information to enable the design of flexible conservation contracts that can be used to optimize environmental benefits, farmer adoption, or acres enrolled. These innovative contracts will help U.S. agriculture remain competitive while balancing production and sustainable agri-environmental benefits.



#### Benefits and Costs of Non-market Valuation Methods for Environmental Management

Principal Investigator: Robert J. Johnston Funding Agency: Australian Research Council

Environmental programs and policies cost billions of dollars per year. Environmental policy makers and managers can be assisted in their decisions on the allocation of public resources to environmental investments by information on the community's preferences for environmental outcomes and actions. Ideally, this information will be expressed as monetary values (i.e., nonmarket values expressed as willingness to pay or willingness to accept) as this allows comparison of benefits and costs of environmental projects, and comparisons of alternative environmental benefits which would otherwise be incommensurate. Examples of these "non-market" benefits include existence values for threatened species, the amenity value of an urban wetland, and the value of recreation in natural places. Recognizing the need to quantify these and other nonmarket benefits, environmental economists have devoted considerable effort to the development and application of a range of non-market valuation (NMV) techniques. These have varying strengths and weaknesses and different techniques are suited to estimating different types of non-market values. This project will develop a rigorous framework for selecting the most appropriate approach to handling NMV information gaps for particular management or policy decisions. The aim of this research is to assist decision makers in three ways: (1) by demonstrating quantitative analyses to support a range of decisions about NMV methods; (2) by developing heuristics about when particular methodological choices are more likely to be preferred; and (3) by assisting decision makers to think through these decisions in a more sophisticated and complete way.

#### Spatially Explicit Ecosystem Service Benefit Transfer for Policy Evaluation: An Integrated Biophysical and Meta-Analytic Approach

Principal Investigator: Robert J. Johnston Funding Agency: U.S. Department of Agriculture

The USDA spends over \$5 billion annually on conservation programs to enhance ecosystem services that promote agricultural sustainability, often targeting benefits such as water quality and aquatic ecosystem services. While the biophysical impacts of these programs can be estimated using established models, the economic benefits are generally unknown. Addressing this shortcoming requires practical, reliable and cost-effective benefit transfer methods explicitly designed for large-scale ecosystem service valuations. Meta-regression models are increasingly used in benefit transfers, and these models can be specified to link directly to biophysical models that predict policy outcomes. Despite this promise, further methodological advances are required if meta-regression models are to be used widely for large-scale ecosystem service valuations. This project will develop and evaluate an integrated biophysical and meta-analytic benefit transfer model designed to estimate spatially explicit ecosystem service benefits from large-scale agricultural conservation policies, while addressing limitations of prior benefit transfer approaches. The new approach will be demonstrated using case studies of conservation programs that enhance aquatic ecosystems.

### Methods and Software to Understand and Build the MapBiomas Data

Principal Investigator: Robert Gilmore Pontius Jr. Funding Agency: Instituto Humanize

MapBiomas is a multi-institutional initiative involving NGOs, universities, think-tanks and tech companies dedicated to developing the most advanced, complete, and detailed time series of annual land cover and land use change maps in Brazil, used to support sustainable management and conservation of natural resources. Map data accuracy derives from various decisions concerning the selection of legend categories and the steps used to process the remotely sensed images. MapBiomas has developed various temporal and spatial filters applied as a post-classification process to eliminate temporal differences derived from data error; however, these filters have various influences on the data and we need a better understanding of these influences. This project will develop new ideas and methods (software and publications) to explain transitions among land cover categories, whether the explanation concerns processes on the ground or errors in the data.

#### Assessing Forest Clearing Rates Near Pellet Mills in Southeastern US Forestlands

Principal Investigator: Christopher A. Williams Funding Agency: Doris Duke Foundation and Southern Environmental Law Center

Wood pellets are increasingly used in many European countries as a renewable fuel source for power stations. Pellet mills in the southeastern United States are supplying much of this cross-Atlantic demand. While the pellet industry claims they are using low-grade trees and wood waste products as inputs to pellet production, environmentalists claim they are using whole hardwood trees resulting in loss of valuable wildlife habitat. This project will compute and test whether current forest clearing rates and temporal trends are significantly different between mill regions and non-mill reference areas. The primary goal of the project is to determine whether the wood pellet industry has altered forest clearing rates in North Carolina and Virginia.

### SUSTAINABLE COMMUNITIES AND LIVELIHOODS

Sustainable communities and livelihoods rely on public and private institutions and governance to determine whether and how people achieve sustainable levels of consumption and ensure the resilience of local populations to regional upheavals and global change. Marsh Institute researchers seek to promote an improved human condition, with particular emphasis on challenges related to disadvantaged populations, and social and environmental justice. Much of this work coordinates closely with community partners to promote positive social change. For example, Halina Brown and Philip Vergragt continue their founding work with the Sustainable Consumption Research and Action Initiative, a network of practitioners focused on facilitating the transition to a more sustainable society. Edward Carr and Anita Fabos are working with the Belmont Forum to address human rights concerns related to the dynamics of involuntary migrations. Margaret Post is evaluating a program that promotes racial and maternal birth equity in low-income communities. John Rogan and Deborah Martin are working with the Massachusetts Executive Office of Energy and Environmental Affairs and the Opacum Land Trust to assess the impact of tree planting on residential heating/cooling and respiratory illnesses in low-income urban communities. Laurie Ross and Jie Park are studying how Latinx families use telehealth and tele-education services, and are identifying barriers to access. Ross and Jennifer Safford-Farquharson are working with The Community Builders to investigate the

relationship between stable housing and gaps in mental health services. **Rinku Roy Chowdhury** is working with a multi-disciplinary team to test the theory that residential neighborhoods across different parts of the U.S. are becoming homogenized, and to determine the ecological implications of alternative futures.



### Promoting Sustainable Consumption Research and Action

Principal Investigators: Halina Brown and Philip Vergragt

Marsh Institute researchers Halina Brown and Philip Vergraat work at the forefront of sustainable consumption research. Brown and Vergragt are Founding Board Members of SCORAI, the Sustainable Consumption Research and Action Initiative, an international network of close to 1400 researchers and practitioners committed to advancing sustainability by focusing on societal patterns of consumption. SCORAI recognizes that technological innovation alone is insufficient to achieve sustainability; changes are required in societal institutions, cultures, and economic systems. SCORAI's mission is to facilitate a transition to a more sustainable society by generating knowledge that impacts discourse and supports change agents. Since 2008, SCORAI network participants have advanced and disseminated knowledge and contributed to policy dialogues and practices, in order to chart pathways towards a more sustainable future. In June 2020, Brown and Vergragt co-organized the fourth International SCORAI Conference on "Sustainable Consumption & Social Justice in an Urbanizing World" jointly hosted by Northeastern University in Boston and KTH Institute in Stockholm. The virtual conference was attended by 350 participants from more than a dozen countries.

#### **Migration, Transformation and Sustainability**

Principal Investigators: Edward Carr and Anita Fabos Funding Agency: National Science Foundation and Belmont Forum

Unprecedented concern exists regarding involuntary migration affecting insecurity and human rights around the globe. However, both domestic and international migration has enormous transformative potential for individuals and societies. Existing theories of transformation fail to recognize both positive and negative impacts of the movement of people. This gap limits explanations and intervention strategies for sustainability. The objective of this research is to expand knowledge of transformations to sustainability by incorporating specific migration dynamics including: the impact of aggregate flows of people on sustainability; the individual life course dimensions of sustainability; and the governance of migration and sustainability. This project will develop a comprehensive migrationsustainability model and identify insights on sustainability strategies at local, national, and international scales. As part of a large interdisciplinary social-science led consortium from Europe, North America, Asia and Africa, this research will build global capacity of social science to explain and engage with migration dimensions of transformations to sustainability.

#### Evaluating the Base Building and Birth Justice Components of the Robert Wood Johnson Foundation Community Power to Build Health Equity Initiative

Principal Investigator: Margaret Post Funding Agency: Center for Evaluation Innovation

Community power is the ability of communities most impacted by inequity to act together to voice their needs and hopes for the future and to collectively drive structural change, hold decision-makers accountable, and advance health equity. The Robert Wood Johnson Foundation (RWJF) supports community power organizations and advocacy networks that engage in grassroots organizing, particularly with people who are low-income, of color, and/or youths. This research project, in collaboration with the Center for Evaluation Innovation and Social Insights Research, will conduct a 40-month evaluation of RWJF's Community Power to Build Health Equity Initiative that is focused on elevating the voices of communities of color and building a broad constituency that promotes local racial equity and maternal/birth equity. As senior researcher, Dr. Post will contribute to the overall leadership and shaping of the project design and implementation; advise and co-develop data collection and analysis plans; report and present results; and participate in meetings with RWJF and other stakeholders to discuss the evaluation.

#### **Community Change Evaluation Projects**

Principal Investigator: Margaret Post Funding Agency: JPB Foundation and Innovation Network

Community Change is an organization that promotes racial justice and equity through education and advocacy programs. This ongoing project provides an outcomes-focused evaluation of Community Change's economic justice initiative, which is funded through grants from the JPB Foundation. The evaluation includes: interviews with key informants knowledgeable about the state of the national conversation on poverty and economic justice; case studies to delve deep into local initiatives and success factors; and evaluation and learning support for strategy development. As Senior Researcher on the evaluation team, Dr. Post will provide overall leadership and shaping of the project design and implementation.

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#### Revitalizing the Hadwen Arboretum, Columbus Park Neighborhood

Principal Investigator: John Rogan Funding Agency: Commonwealth of Massachusetts, Department of Conservation and Recreation

In collaboration with the Worcester Tree Initiative, Tower Hill Botanical Garden, and Columbus Park Neighborhood Residents Association, this project will embark on a revitalization of the Hadwen Aboretum in Worcester, Massachusetts. Historically, the site was home to over 100 different tree varieties, including 15 different varieties of Magnolia trees. Despite the significance of the Arboretum to tree experts and local residents, the site lacks tree tags and proper signage, and contains numerous invasive species and a large cohort of mature overstory trees, some of which are dying or dead. After years of neglect, a new forest management plan calls for tree tagging, brush removal, new tree plantings, new trail development, and improved signage and access for visitors. The project will connect student classroom training with on-the-ground experience in forest management practices by engaging students in revitalization activities. Results of the project will be shared via online maps, a public website, and community events, and will inform long-term goals for the Arboretum.



#### Tree Planting for Cooler Summers and Cleaner Air in Partnership with a Community Hospital, Outpatient Center and Land Trusts to Improve Health Conditions for High Risk Populations in Two Small, Low-income Cities

Principal Investigators: John Rogan and Deborah Martin Funding Agency: U.S. Forest Service and Opacum Land Trust

The Massachusetts communities of Ware and Southbridge have significantly above average incidence of respiratory conditions among their populations and low existing tree canopy cover. In a unique partnership among cities, community health care facilities, grassroots neighborhood centers, and regional land trusts, this project will focus on the ability of cost-effective and spatially-strategic community tree planting to cool low income neighborhoods, shade walking routes, and filter pollution near schools. In so doing, it meets several high priorities for Massachusetts' Forest Action Plan. As an extension of their ongoing research in Massachusetts Gateway Cities, Clark University HERO Fellows will be responsible for the placement and maintenance of temperature and air quality monitoring equipment, as well as data analysis and reporting.

#### Measuring Temperature Sensor Data in Massachusetts Gateway Cities

Principal Investigator: John Rogan Funding Agency: Commonwealth of Massachusetts, University of Massachusetts Amherst

Urban areas experience higher temperatures than surrounding non-urban areas due to differences in land-cover, especially impervious surfaces. The presence of an urban tree canopy can regulate and counteract these elevated land surface temperatures, thus reducing energy usage especially during summer peak energy load periods. The Greening the Gateway Cities (GGC) Program, created by the MA Executive Office of Energy and Environmental Affairs, is designed to reduce household heating and cooling energy use by increasing tree canopy cover in urban residential areas. This project will collect and analyze daily-monthly-annual air temperature and humidity data from a network of HOBO weather stations in three GGC cities to assess differences among tree planting zones. Additionally, the project will employ a three-dimensional microclimate model (ENVI-met), calibrated using the HOBO data, to simulate the impact of tree planting on microclimate using four different scenarios: (1) no new tree cover; (2) current GGC tree cover; (3) idealized GGC tree cover (i.e., trees in all available open spaces); and (4) micro-climate conditions under future climate.



#### Equity from the Start: Latino/a/x Families' Experiences with Tele-Education and Telehealth due to COVID-19

Principal Investigators: Laurie Ross and Jie Park Funding Agency: American Education Research Association

With COVID-19, home visiting programs for young children and their caregivers have shifted to telehealth and tele-education—a shift that has exacerbated the psychosocial, education, and mental health disparities in poor communities of color, but also highlighted the resilience and adaptive capacity of Latino/a/x families. This transition involves fundamental shifts in how families perceive and approach the care they receive, and how providers create meaningful interactions with families and young children. Yet organizations and providers are unsure of how families are experiencing telehealth and/or tele-education, leading them to make decisions that are not informed by data or responsive to families' strengths and needs. Using data from focus group conversations with Latino/a/x caregivers who have participated in telehealth and/or tele-education, this project will improve our understanding of Latino/a/xfamilies' uses of and experiences with telehealth and tele-education, targeting not only barriers to access, but also families' strategic leveraging of services. In addition, the project will support the development of practice and policy guidelines that will be disseminated to the Together for Kids Coalition's 50+ partner organizations and agencies.

#### Shannon Community Safety Initiative: Worcester Local Action Research Partner

Principal Investigators: Laurie Ross and Jennifer Safford-Farquharson Funding Agency: Massachusetts Executive Office of Public Safety and Security

The Senator Charles E. Shannon Community Safety Initiative (Shannon CSI) supports regional and multidisciplinary approaches to combat gang violence through coordinated programs for prevention and intervention. These multi-disciplinary approaches include, but are not limited to, law enforcement initiatives such as anti-gang task forces and targeting of enforcement resources through the use of crime mapping; focused prosecution efforts; programs aimed at successful reintegration of released inmates and youth from juvenile detention; and programs that provide youth with supervised out-ofschool activities. Working in partnership with the City of Worcester, the Worcester Police Department, the Boys & Girls Club of Worcester, Straight Ahead Ministries, the Worcester Community Action Council, and the Worcester Youth Center, Ross and Safford-Farguharson serve as the Shannon CSI Local Action Research Partner for Worcester, providing strategic research support and program evaluation of city-wide gang violence prevention and intervention.



### Boston Children's Collaboration for Community Health

Principal Investigators: Laurie Ross and Jennifer Safford-Farquharson Funding Agency: Boston Children's Hospital and The Community Builders

The Community Builders (TCB) is a nonprofit developer, owner and manager of affordable and mixed-income housing. Through engagement with property management and staff, health providers, and residents, this project will implement the Boston Children's Collaboration for Community Health program and facilitate the efforts of TCB and its partners to improve the quality, timeliness, and holistic care of crisis intervention, longer-term mental health services, and housing stabilization support for TCB children and families.

#### **Trauma and Housing Stability**

Principal Investigators: Laurie Ross and Jennifer Safford-Farquharson Funding Agency: Blue Cross Blue Shield Foundation and The Community Builders

The Community Builders (TCB) is a nonprofit developer, owner and manager of affordable and mixed-income housing. Community Life is TCBs place-based model that provides stable and healthy housing as a platform for residents and neighborhoods to address some of the most significant challenges facing low-income populations through six key practice areas: youth development, education, workforce development, health, asset building, and community engagement. Through engagement with property management and staff, health providers, and residents, this project will facilitate the efforts of TCB and its partners in understanding the connection between stable and healthy housing and trauma and gaps in mental health services, and recommend future steps for implementing TCB's Worcester Beyond Healthcare program.

### Alternative Ecological Futures for the American Residential Macrosystem

Principal Investigator: Rinku Roy Chowdhury Funding Agency: National Science Foundation

An apparent, but untested, result of changes to the urban landscape is the homogenization of cities, such that neighborhoods in very different parts of the country increasingly exhibit similar patterns in their road systems, residential lots, commercial sites, and aquatic areas; that is, cities have now become more similar to each other than to the native ecosystems that they replaced. This research examines the ecological homogenization of the American Residential Macrosystem (ARM) and specifically investigates factors that contribute to stability and/or changes in the ARM. The aim is to determine how factors that effect change—such as shifts in human demographics, desires for biodiversity and water conservation, regulations that govern water use and quality, and dispersal of organisms-will interact with factors that contribute to stability such as social norms, property values, neighborhood and city covenants and laws, and commercial interests. The project will determine ecological implications of alternative futures of the ARM for the assembly of ecological communities, ecosystem function, and responses to environmental change and disturbance at parcel (ecosystem), landscape (city), regional (Metropolitan Statistical Area), and continental scales. Five types of residential parcels as well as embedded semi-natural interstitial ecosystems will be studied, across six U.S. cities (Boston, Baltimore, Miami, Minneapolis-St. Paul, Phoenix, and Los Angeles).

The Marsh Institute is home to several partner facilities including research centers and labs, stakeholder education and outreach programs, and a research library all focused on supporting Clark University's extensive environmental academic and research programs as well as the broader community to foster local and global long-term environmental sustainability. The Humanitarian Response and Development Lab is a development and humanitarian assistance research and implementation lab that collaborates with global partners such as the World Bank and Red Cross Climate Center. The Clark Center for the Study of Natural Resource Extraction and Society promotes the collaborative efforts of Clark faculty and students on extractive industries, infrastructure investment, energy, and agroindustry. The **Blackstone Watershed Collaborative**—a new network of nonprofits, universities, businesses, and others seeking to improve the health and resilience of the watershed — convenes stakeholders and offers technical assistance, outreach, and educational materials. The Jeanne X. Kasperson Research Library offers one of the most extensive collections in North America on environmental risk and hazards, environment and development, and the human dimensions of global environmental change. The Marsh Institute also collaborates with other research centers and labs at Clark University including **Clark Labs**, which develops innovative and customized geospatial research tools, the Agricultural Impacts Research Group, which focuses on how agricultural development can be achieved with lower environmental and social costs, the **Biogeosciences Research** Group, which explores how earth's biosphere responds to natural and human perturbations such as drought events and forest fires, and the Polar Science Research Laboratory, which investigates linkages between land surface, ice cover, oceans and the atmosphere in polar regions.

> CENTERS AND PROGRAMS

### HUMANITARIAN RESPONSE AND DEVELOPMENT LAB

The Humanitarian Response and Development Lab (HURDL) is a development and humanitarian assistance research and implementation lab. Led by IDCE Director Ed Carr, HURDL scientists and student researchers are engaged in projects that range from policy development to project design and

implementation. This diverse portfolio of activities is unified by a shared belief that the challenges we see in the Global South are products of various forms of risk and uncertainty that limit the potential for locally generated innovations that could change the lives of the poor. HURDL collaborates with many different organizations including the World Bank, the Red Cross Climate Center, the International Research Institute for Climate and Society, and the

Climate Services Partnership, among others, creating a broad network of experience and expertise to inform its work. This past year, Helen Rosko (right) and Mario Machado (far right) joined HURDL as research scientists. More information can be found on the lab's website (www.hurdl.org)



### CENTER FOR THE STUDY OF NATURAL RESOURCE EXTRACTION AND SOCIETY

The Clark Center for the Study of Natural Resource Extraction and Society (Extractives@Clark) promotes the collaborative efforts of Clark faculty and students on extractive industries,

infrastructure investment, energy, and agroindustry. Center research—led by Professors Denise Humphreys Bebbington (IDCE), Tony Bebbington (Geography) and John Rogan (Geography)—involves policy and practical engagements with philanthropic, non-governmental, and public sector bodies. For example, research into the effects of extractive industry and large-scale infrastructure on forest cover and human rights in the Amazon, Central America, Mexico and Indonesia involved Clark researchers in direct discussions with the Climate and Land Use Alliance regarding the implications of their findings for the Alliance's work. Researchers at the Center have also worked closely with Oxfam on elements of its Extractive Industries program, advising on overall global and Latin American strategy, and conducting research designed to feed into program and policy design in Honduras, Peru and East Africa in particular. In addition to faculty researchers, the center is home to research scientists Nick Cuba

and Laura Sauls, and graduate students Maria del Pilar Delpino Marimon (right) and Andrea Cabrera Roa (far right). This past year, the Center hosted a virtual seminar series and a screening of the documentary ¿Qué les pasó a las abejas? (What happened to the bees?) More information can be found on the center's website (www.extractivesatclark.org).



### BLACKSTONE WATERSHED COLLABORATIVE

The Blackstone Watershed Collaborative is a network of nonprofits, universities, businesses, and others seeking to improve the health and resilience of the watershed which spans 48 miles and 39 communities from Worcester, MA to Pawtucket, RI. The Blackstone River and its watershed

have been vital to the ecological, social, and economic health of the region for centuries. Along with the Taunton River, the Blackstone provides freshwater to the Narragansett Bay downstream and supports ecological health through large intact forests and cold-water fisheries as well as thriving commercial and recreational benefits such as fishing, kayaking, and biking. Local efforts since 1970 have succeeded in reducing pollution from legacy industrial sites, large wastewater treatment plants, and new development, removing waterways from the impaired water list, opening upstream fish habitat, and fostering collaboration among diverse stakeholders. Local river advocates have devoted tireless efforts to address the watershed's industrial past and ongoing urbanization. Despite this progress, work is still required to assure a healthier and more resilient watershed over the coming years.





kstone Watershed Collaborative

Building upon decades of dedicated work by volunteers, planners, educators, activists, scientists, and water quality monitors, the Blackstone Watershed Collaborative was established in 2021 to convene stakeholders throughout the bi-state watershed and offer technical assistance, outreach, educational materials, and networking to advance the 21 priority goals of the 2021 Blackstone River Watershed Needs Assessment Report. The Collaborative acts as an

umbrella organization to facilitate and coordinate the work of over 140 partner organizations including watershed associations, land trusts, universities, federal/state/local agencies, consultants, and others to share the most recent data, publications, tools, and resources. A major part of the program's effort is focused on matching priority projects with available funding.

Located in the Marsh Institute, Program Manager Stefanie Covino (right) leads the effort to create a thriving and sustainable Blackstone Watershed Collaborative that will support restoration activities, develop communication and messaging, educate decision-makers, and promote new programs and policy for the benefit of all that work, live, and recreate in the watershed. More information can be found on the program's website (www.blackstonecollaborative.org).



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### JEANNE X. KASPERSON RESEARCH LIBRARY

The Jeanne X. Kasperson Research Library is dedicated to higher learning and to supporting those who seek to expand their knowledge. The primary mission of the library is to support Clark University's extensive environmental research and global change programs. This includes but is not limited to programs conducted

under the aegis of the Marsh Institute, the Graduate School of Geography, and the Department of International Development, Community, and Environment (IDCE). The library is committed to serving the educational functions of Clark University and the broader community in order to further research related to socio-environmental sustainability. One of the integral parts of the Marsh Institute, the Kasperson Library offers one of the most extensive collections in North America on environmental risk and hazards, environment and development, and the human dimensions of global environmental change. The library also has significant holdings on the subjects of sustainable development, environmental technology, water resources, and energy policy, as well as other unique special collections such as its extensive holdings on radioactive waste management. Most recently, the library became home to the Worcester Refugee Archive, a collection of local and global resources on the topic of refugee resettlement in Worcester County. In addition to journal articles, the archive contains theses, government reports, and newspaper articles dating back to the 1970s. The library has attained national and international recognition as a premier collection of research materials, and particularly of fugitive materials and unpublished literature in its areas of specialization. It provides information and research support for university researchers;

undergraduate and graduate students; visiting scholars; regional experts; federal, state, and local agencies; industry; schools; and consulting firms. The library currently has more than thirty-five thousand volumes, journals related to the library's focus areas, and computer and internet resources. Library Director BJ Perkins (right) and other library staff provide personalized research assistance.



### **IN MEMORIAM: ROGER E. KASPERSON**



Roger E. Kasperson, Professor Emeritus of Geography and former Director of the Marsh Institute, passed away peacefully in April. Professor Kasperson's many roles at Clark University included University Professor, Acting Director of the Graduate School of Geography, Dean of the College, and Provost and Vice President for Academic Affairs. He was one of the first geographers to be elected a member of the National Academy of Sciences, and authored or co-authored 24 books and monographs, and more than 150 articles. Memorial donations can be directed to the Jeanne X. Kasperson Library. The Marsh Institute provides innovative, applied research opportunities for Clark graduate and undergraduate students. Programs range from endowed awards for student-initiated research to large-scale research projects promoting student involvement and hands-on learning, often in interdisciplinary and multi-institutional settings. Among these programs, the annual Albert, Norma and Howard Geller '77 Endowed Research Awards support student-initiated research projects that advance our understanding of natural resource and environmental sustainability and develop practical improvements that move society toward more sustainable outcomes. Each year, the Human-Environment Regional Observatory (HERO) program provides funding for a cohort of select undergraduate students to engage in research on human-environment relationships in Massachusetts. For eight weeks during the summer, HERO Fellows conduct hands-on research under the mentorship of Clark University faculty and graduate students. Faculty-led research projects involving students cover a range of topics including: investigating climate change impacts on marine ecosystems in the Pacific Arctic region, developing a scalable and cost-effective agricultural land-cover mapping program in sub-Saharan Africa, modeling water supply and wastewater-sanitation systems for the Mexico City Basin, surveying homeowners in Long Island Sound regarding their lawn care practices, and identifying and predicting changes in coastal vegetation in the Plum Island (Massachusetts) Ecosystem. Students are engaged in all aspects of the research from data collection and analysis through presentation and publication of results. Throughout 2020-21, Marsh Institute grants and endowments supported eight undergraduate students, thirty-two graduate students, and three post-doctoral fellows.

## STUDENT RESEARCH

### HUMAN-ENVIRONMENT REGIONAL OBSERVATORY

Built on over 20 years of success, the Human-Environment Regional Observatory (HERO) program is a unique undergraduate-graduate-faculty collaborative that conducts research on human-environment relationships in Massachusetts. Under the mentorship of faculty advisors John Rogan and

**Deborah Martin**, HERO Fellows analyze the causes and consequences of global environmental changes at local scales. Among its many benefits, the HERO program provides students with opportunities to conduct, present, and publish research alongside faculty colleagues. HERO research has been funded by multiple awards from the National Science Foundation Research Experiences for Undergraduates (REU), the National Marine Fisheries Service, the Thoreau Foundation, the Commonwealth of Massachusetts, and the John T. O'Connor '78 Endowed Fund for Environmental Studies.



2021 HERO Fellows (L-R): Apple Gould-Schultz, Caleigh McLaren, Madeline Regenye, David Henriques, and Sarah Hughes

Since 2012, HERO Fellows have monitored the health of trees replanted in the Worcester area after one of North America's largest infestations of the Asian longhorned beetle. As data collected by HERO's undergraduates show, the Worcester Tree Initiative and Massachusetts Department of Conservation and Recreation's program to replant 30,000 trees in residents' yards has largely proven successful. In 2017, the HERO program expanded its research goal to include cities that face a dearth of trees due to their industrial past. These cities are part of Massachusetts' Greening the Gateway Cities Program, which aims to increase tree canopy by 10 percent in 26 former factory towns by providing trees to residents and planting trees along city streets. In 2020 and 2021, field research in the Gateway Cities was suspended due to the COVID-19 pandemic. Instead, HERO Fellows gained experience in forest

management practices at Clark's Hadwen Arboretum including tree tagging, brush removal, new tree plantings, new trail development, and improved visitor signage. HERO Fellows will spend the upcoming academic year working on individual research projects and present their findings during Clark's Academic Spree Day.



**2021 Graduate Student Managers:** Nick Geron (left) and Marc Healy (right)

### GELLER ENDOWED STUDENT RESEARCH AWARDS

Coordinated by Marsh Institute Assistant Director **Dana Bauer**, The Albert, Norma and Howard '77 Geller Endowed Research Awards support student-initiated research projects that advance our understanding of natural resource and environmental sustainability.

Remembering his own experience as an activist student researcher at Clark, Dr. Howard Geller (Science, Technology, and Society '77) hopes to support other Clark students combine research with action that moves society toward sustainable outcomes.



Julia Dowling BA Geography and Urban Development Faculty Mentor: Asha Best

#### A Mixed Methods Ethnography of Cooperative Projects in Uneven Urban Development in Worcester, MA

Worcester, MA, in facing pressures to be a competitive and economically 'developed' city, has invested in its downtown including the construction of a new baseball stadium and the strategic reconstruction of streetways. However, this gentrification process is simultaneously closing in on spaces youth can occupy without pressure to spend money (e.g., the demolition of a popular youth-oriented skate park). The city government's goals do not always align with the needs of community members, especially those who are economically marginalized. This displacement and fragmentation of space has prompted a response by grassroots organizations such as Save the Bridge, a collective and vision for a trade-school and shelter in an old mill building, and Mutual Aid Worcester, which provides funds and food to individuals and families in immediate crisis. This Geller endowed project uses experimental mixed-methods to create a well-rounded understanding of these organizations' work, from both the organizers' and the beneficiaries' perspectives. This research will shed light on the unquantifiable value of such organizations, and on the lived realities of residents coping with urban change in Worcester, MA.



Marc Healy PhD Geography Faculty Mentor: John Rogan

#### Evaluating urban tree management strategies and municipal structure to identify the effects of recent plantings on municipal stewardship

Urban forests are directly impacted by numerous actors ranging from tree nurseries, forestry or public works departments, non-profits organizations, and local residents. These stakeholders can create a complex web of governance around the planting and care of urban trees. Characterizing the level of management and resources used for urban forestry can help explain the impacts and benefits on municipal government. This Geller endowed project will analyze how the maintenance and care of trees by 14 Massachusetts municipalities was affected by a state-led tree planting program. This research seeks to understand in what ways municipal forestry departments react to non-municipal led tree planting and how it affects their level of management and care. Data will be collected through semi-structured, open-ended interviews with tree wardens or associated persons at each city and compared to national averages. Qualitative themes will be analyzed to understand tree care changes pre- and post-planting, as well as impacts on municipal governance. This research can offer insights for other cities that have external planting programs and provide guidance on how management practices can be used within this context.

### THE PACIFIC ARCTIC MARINE ECOSYSTEM

Professor Karen Frey and students Clare Gaffey (PhD Geography),

Sophie Spiliotopoulos (MS GIScience) and Anna Zhu (PhD Geography) aboard the Canadian Coast Guard Ship Sir Wilfrid Laurier, collecting data on the changing biology of the Bering and Chukchi Seas under the Distributed Biological Observatory research project. Student research is combining cruise-collected samples with remotely sensed satellite data and GIScience to examine changing patterns of marine populations due to declines in sea ice.





### THE MEXICO CITY SOCIAL-ECOLOGICAL REGION

Professor Timothy Downs, doctoral student Ravi Hanumantha, professor Yelena Ogneva-Himmelberger, and professor Morgan Ruelle enjoying a break during field work in the Mexico City region. A collaboration between Clark University and National Autonomous University of

Mexico, research is focused on integrating diverse data and perspectives to understand and identify resilient solutions to impacts that climate change is having on water availability and sanitation systems throughout the region. Nine Clark undergraduate and master's students are also engaged in project research.

### THE PLUM ISLAND ECOSYSTEM LTER SITE

Visiting scholar Ramon Molinero, doctoral student

Thomas Bilintoh, professor **Gil Pontius**, master's student Claire Wang, Mass Audubon scientist Robert Buchsbaum, and doctoral student Aiyin Zhang (left to right) conducting fieldwork at the Plum Island Ecosystem Long-Term Ecological Research (LTER) site in northeastern Massachusetts. Several students conducting individual research at the site presented their findings at the American Association of Geographers Annual Meeting, with three students winning awards.



The Marsh Institute is home to scholars from a variety of social and natural science disciplines, including anthropology, chemistry, computer science, ecology, economics, engineering, geography, geospatial sciences, history, hydrology, management, political ecology, physics, and sociology. Each year brings new individuals and expertise to the institute; this year, the institute added expertise in urbanism and climatology.



YUKO AOYAMA Geography



DANA BAUER Marsh Institute



ANTHONY BEBBINGTON Geography



ASHA BEST Geography



HALINA BROWN Marsh Institute



CYNTHIA CARON IDCE



EDWARD CARR IDCE



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MARK DAVIDSON Geography



TIMOTHY DOWNS IDCE



RONALD EASTMAN Geography



LYNDON ESTES Geography



ELLEN FOLEY IDCE



ABBY FRAZIER Geography



KAREN FREY Geography

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ROBERT GOBLE Marsh Institute



WAYNE GRAY Economics



NATALIA HASLER Marsh Institute



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JIE PARK Education



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LAURIE ROSS IDCE



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CHRISTOPHER WILLIAMS Geography



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JING ZHANG Management



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### 2020-21 MARSH INSTITUTE STEERING COMMITTEE

#### **Anthony Bebbington**

Professor, Graduate School of Geography

**Edward Carr** Professor and Director, International Development, Community, and Environment

**Timothy Downs** Associate Professor, International Development, Community, and Environment

Lyndon Estes Associate Professor, Graduate School of Geography

Karen Frey Professor, Graduate School of Geography

Robert Goble Research Professor, George Perkins Marsh Institute

Deborah Martin Professor, Graduate School of Geography Steering Committee members are chosen to represent the diversity of the Marsh Institute's research areas and include some of the most prominent researchers at Clark University. Members are also chosen based on a history of involvement with the institute and a dedication to its continued success.

#### Laurie Ross

Professor, International Development, Community, and Environment

Rinku Roy Chowdhury Associate Professor, Graduate School of Geography

Christopher Williams Professor, Graduate School of Geography

#### **EX-OFFICIO MEMBERS**

Yuko Aoyama Dean of Research and Graduate Studies; Professor, Graduate School of Geography

Dana Marie Bauer Assistant Director, George Perkins Marsh Institute

Robert J. Johnston Director, George Perkins Marsh Institute

### NEW FACES AT THE INSTITUTE



#### Asha Best

Asha Best is an urbanist whose research and teaching is interdisciplinary. Her work links mobilities studies, post-colonial and black studies, critical race theory, and studies of urban informality. She is particularly interested in popular, improvised, and often unofficial urban practices deployed by black and migrant groups, and her research looks at how those practices impact how cities are understood, planned and mapped. She is developing a comparative research project around black and migrant place-making, informality and mobilities in the context of Johannesburg. Dr. Best received her Ph.D. in American Studies from Rutgers University-Newark.



#### **Abby Frazier**

Abby Frazier is a climatologist who studies the spatiotemporal dynamics and impacts of climate change and climate variability. Her research uses geospatial analysis to understand the mutli-disciplinary impacts of climate on freshwater resources and ecosystems over regional and global scales, with a focus on Pacific Islands. She is interested in climate extremes, particularly the impacts of drought and the El Niño-Southern Oscillation on local hydrology and wildfire regimes. She collaborates closely with stakeholders to co-produce actionable science to support climate change decision making and natural resource management. Dr. Frazier earned her Ph.D. and M.A. degrees in geography from the University of Hawai'i at Mānoa.

### PANELS, EDITORSHIPS AND OTHER AWARDS

The international expertise of Marsh Institute researchers is reflected in their presence on top-level science advisory boards and committees, as well as invitations to provide regional, national and international policy guidance. In addition, national and international awards reflect the contributions, expertise and reputation of institute scientists.

#### **ADVISORY BOARDS AND COMMITTEES**

Anthony Bebbington is a member of the US National Academy of Sciences and serves on its Diversity Committee for the Human-Environment Sciences section.

Anthony Bebbington is serving a 3-year term as chair of the Programs Committee for Oxfam America.

Halina Brown is chairperson of Newton (Massachusetts) Citizens Commission on Energy and Philip Vergragt cochairs the Newton Task Force on Electric Vehicles, both of which are part of the implementation of the Newton Climate Action Plan.

**Edward Carr** is a lead author on the Intergovernmental Panel on Climate Change's Sixth Assessment Report.

**Edward Carr** serves as the Climate Change Adaptation Adviser on the Global Environmental Facility's (GEF) Scientific and Technical Advisory Panel.

Abby Frazier has been selected to lead the Hawai'i and U.S.-affiliated Pacific Islands chapter of the U.S. Global Change Research Program's Fifth National Climate Assessment.

**Karen Frey** serves as Vice Chair of the Marine Working Group of the International Arctic Science Committee.

**Elisabeth Gilmore** is a lead author on the Intergovernmental Panel on Climate Change's Sixth Assessment Report.

**Denise Humphreys Bebbington** serves on the Advisory Council of the CASA SocioEnvironmental Fund.

**Robert Johnston** is Co-Chair of the Ecosystem Science and Management Working Group of the NOAA Scientific Advisory Board.

**Robert Johnston** serves on the Senior Advisory Board of the Connecticut Sea Grant College Program.

**Robert Johnston** serves on the Steering Committee and Scientific Advisory Committee of the Narragansett Bay Estuary Program.

James Murphy was elected Corresponding Member of the Section of Technical Sciences at the Royal Academy of Overseas Sciences in Belgium.

**Robert (Gil) Pontius** serves on the Scientific Advisory Committee of MapBiomas. **Rinku Roy Chowdhury** is a lead author of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services Global Assessment Report.

**Rinku Roy Chowdhury** is co-chair of the Scientific Steering Committee of the Global Land Programme.

**Christopher Williams** is leader of the Science Implementation Plan for the North American Carbon Program.

#### EDITORSHIPS AND PROFESSIONAL SERVICE

**Anthony Bebbington** is Associate Editor at World Development and Editor at the Proceedings of the National Academy of Sciences.

Halina Brown and Philip Vergragt are co-editors of the Routledge-SCORAI book series Studies in Sustainable Consumption.

**Robert Johnston** serves as editor of Resource and Energy Economics and serves on the editorial boards of the journals Coastal Management and Journal of Environmental Economics and Policy.

James Murphy serves as Editor-in-Chief of Economic Geography, which has been owned and operated by Clark University since 1925.

#### AWARDS AND RECOGNITIONS

Asha Best and Lyndon Estes received the Ronan Paddison Seminar Series Award from the Urban Studies Foundation which will provide funding for their upcoming seminar program Methodologies for Just Urban Futures: Using Geospatial Tools to Address Police Violence.

Lyndon Estes was awarded the George Perkins Marsh Institute Award for the 2021-2022 academic year. The award goes to a Graduate School of Geography faculty member who has contributed substantially to the institute's research grant portfolio. Estes is overseeing five projects with over \$2.1 million in total budgets.

**Deborah Woodcock** was granted Honorary Membership in Sociedad Geológica del Peru for her contributions to paleontology in Peru.

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### RECENT BOOKS AND OTHER PUBLICATIONS

Each year researchers at the Marsh Institute author dozens of peer reviewed articles in top scientific journals, along with books, chapters and technical reports. These publications advance scientific methods, report empirical findings, and inform both public and private decisions. Examples of recent publications include:

Bernadette Arakwiye (PhD Geography), John Rogan, and Ron Eastman published the article "Thirty years of forest-cover change in Western Rwanda during periods of wars and environmental policy shifts" in the journal Regional Environment Change.

**Dana Bauer** and colleagues published the article "Using landscape metrics to characterize towns along an urban-rural gradient" in the journal *Landscape Ecology*.

**Edward Carr** published the article "Resilient livelihoods in an era of global transformation" in the journal *Global Environmental Change*.

George Gardner (PhD Economics) and Robert Johnston published the article "Is shoreline armoring a response to marsh migration? Modeling relationships between coastal marshes and private adaptation decisions" in the journal Water Resources and Economics.

**Elisabeth Gilmore** and colleague Halvard Buhaug published the article "Climate mitigation policies and the potential pathways to conflict: Outlining a research agenda" in the journal WIRES CLIMATE CHANGE.

**Robert Johnston** and colleagues published the article "Guidance to enhance the validity and credibility of environmental benefit transfers" in the journal *Environmental and Resource Economics*.

**Robert (Gil) Pontius** published the book entitled Metrics That Make a Difference: How to Analyze Change and Error which provides methods and software essential to analyzing change and error and offers insights necessary to interpret metrics that make a difference in life's decisions.



Laurie Ross was lead author on the 2021 Worcester Youth Violence Assessment, a study conducted every three years, which concluded that incidents of violence have decreased but racial inequities persist.

**Morgan Ruelle** and colleagues published the article "Medicinal plants and health sovereignty in Badakhshan, Afghanistan: Diversity, stewardship, and gendered knowledge" in the journal *Human Ecology*.

#### Florencia Sangermano, Robert

(Gil) Pontius, Jamieson Chaitman (MSGIS) and colleagues published the article "Linking land change model evaluation to model objective for the assessment of land cover change impacts on biodiversity" in the journal Landscape Ecology.

Philip Vergragt and colleagues published the book Sustainable Lifestyles after COVID-19 which takes an in-depth look at COVID-19-generated societal trends and develops scenarios for possible future directions of urban lifestyles.



Christopher Williams, Natalia Hasler, and Li Xi (PhD Geography) published the report Avoided Deforestation: A Climate Mitigation Opportunity in New England and New York for the U.S. Climate Alliance Natural and Working Lands Research Program.



**Deborah Woodcock** and colleague Herb Meyer of the U.S. National Park Service published the article "A volcanic eruption 39 million years ago buried a forest in Peru—now the petrified trees are revealing South America's primeval history" in *The Conversation*.

#### **About George Perkins Marsh**

George Perkins Marsh (March 15, 1801–July 23, 1882) was an American diplomat, scholar of languages, and designer of buildings including the Washington Monument. As a congressman in Washington, Marsh helped to found and guide the Smithsonian Institution. He is considered by many to be America's first environmentalist. Over one hundred and sixty years ago he warned of our destructive ways in an insightful book Man and Nature. He was the first to raise concerns about the detrimental impact of human activities on the environment. The conventional idea held by geographers of the day was that the physical aspect of the earth was entirely the result of natural phenomena, mountains, rivers, and oceans. No one had ever turned to the study of the earth as the home of humankind. Marsh was the first to describe the interdependence of environmental and social relationships.



#### You Can Help

The George Perkins Marsh Institute is devoted to the use of science to inform policy and motivate positive change. We also train the scientists and environmental leaders of tomorrow. Your donation to the Marsh Institute allows us to continue our mission — promoting sustainable environments for the public good. Make your tax-deductible contribution to the Marsh Institute through the Clark Fund and join our community of scholars. Please specify the George Perkins Marsh Institute as the designation for your Clark Fund donation. If you would like to discuss ways that your gift can make a difference, please contact our Director, Robert J. Johnston.



GEORGE PERKINS MARSH INSTITUTE

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