

# SUSTAINABLE ENVIRONMENTS FOR THE PUBLIC GOOD

Highlights, Accomplishments and Impacts of The George Perkins Marsh Institute  
Annual Report 2019-20



CLARK  
UNIVERSITY



**GROUNDING IN NEARLY A CENTURY OF APPLIED RESEARCH AT CLARK UNIVERSITY, THE GEORGE PERKINS MARSH INSTITUTE** studies the socio-ecological, technical, institutional and other systems through which humans interact with their surrounding environments. Working within a collaborative agenda, the Institute coordinates resources from Clark University and elsewhere to study human transformation of the environment and responses to this change. The Institute promotes collaborative, systems-based research that challenges traditional disciplinary boundaries to address some of the most pressing issues facing today's world. The Institute's research covers three core research themes linked by cross-cutting topics. Our primary research themes include: ① Socioecological (or human-environment) Systems and Sustainability Science, ② Earth System Science, and ③ Institutions and Human Development. Cross-cutting topics reflect areas of particular importance that are studied through these scientific lenses. Recent cross-cutting topics include: Climate Change Impacts and Adaptation, Local and Global Food Security, and Sustainable Communities.

# HIGHLIGHTS, ACCOMPLISHMENTS AND IMPACTS OF THE GEORGE PERKINS MARSH INSTITUTE ANNUAL REPORT 2019-20

The George Perkins Marsh Institute studies and solves real-world problems from local to global scales. The Institute advances basic and applied science, engages with decision makers and the public, provides learning opportunities for students, and communicates with multiple audiences. We also promote the success of other departments, centers and institutes across Clark University that share our commitment to science in the public interest. The Institute is set apart by its focus on sustainability science and social welfare related to a wide spectrum of challenges ranging from pollinator declines to urban youth violence. This work recognizes that human actions are now causing fundamental changes in global systems. The resulting non-linearities, tipping points and regime shifts challenge our understanding of human-environment interactions and lead to deep uncertainties for decision-making.

The Marsh Institute is home to approximately fifty research faculty and staff, many of whom have joint appointments with other Clark University departments. Grants to Institute researchers support work across a wide range of topics, from assessing damages from marine plastics to improving resilience to drought risk to understanding the relationship between stable housing and mental health services. We work with partners that range from individual farmers and households, to communities, to organizations working at national or global scales. Key themes include climate change impacts and adaptation, ecosystem service provision and conservation, human livelihood protection, and sustainable communities.

The Marsh Institute is one of the most productive hubs for research activity at the University, regularly generating approximately 50% of the University's external research funds. New research projects initiated during 2019-20 address topics such as:

- Examining public values and support for Southern New England shellfish aquaculture expansion programs;
- Engaging students in science for international environmental decision making;
- Modeling tree-planting impacts on microclimate within Massachusetts Gateway Cities;
- Assessing the impact of sea ice reductions and increasing seawater temperatures on marine ecosystems in the Arctic;
- Characterizing rural agricultural production in Africa using remote sensing;
- Improving estimates of carbon benefits from avoided forest conversion in New England and New York;
- Modeling the dynamics of lawn care behaviors in the Long Island Sound;

- Facilitating spatially-strategic tree planting for healthy neighborhoods in two Massachusetts communities;
- Developing guidelines for selecting the best method(s) for the economic valuation of ecosystem services

External support for these and other Institute activities comes from federal, state, local and international grants, private donations, foundations, and other sources.

In addition to our funded research activities, the Institute convenes workshops, conferences and seminars involving scientists, students, stakeholders and decision makers. Institute researchers play important roles in national and international science advisory bodies such as the U.S. National Academy of Sciences, the Global Land Program, North American Carbon Program, International Arctic Science Committee, and the NOAA Science Advisory Board Ecosystem Science and Management Working Group. These and other advisory, outreach and communication activities help ensure the impact of the Institute's work, and connect Institute researchers to local, regional, national and international decision making.

The Institute also provides research opportunities for Clark graduate and undergraduate students. Dozens of students participate in the Institute's externally funded research projects each year. Dedicated programs for student research include the Albert, Norma and Howard '77 Geller Research Grants and the Human-Environment Regional Observatory (HERO) research program in Massachusetts. Building on programs such as these, the Institute provides opportunities for student research within our many communities of practice. We also support outside students and scholars who visit the Institute on a short- or long-term basis, often to work with resident researchers on collaborative research projects.

Among the facilities, offices and centers that comprise the 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 work closely with numerous departments and institutes across Clark University, including the Graduate School of Geography, the Department of Economics, the Department of International Development, Community and Environment (IDCE), 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.



## SOCIOECOLOGICAL SYSTEMS AND SUSTAINABILITY SCIENCE

Among the most pressing challenges facing human society are those involving relationships between humans and natural systems. Researchers at the Marsh Institute were among the pioneers of sustainability science, and the Institute remains a world leader in this critical area of work. This work is increasingly urgent, as demonstrated by the increasing scope, scale and speed of human impacts on the global environment. Research in this area requires multidisciplinary perspectives that recognize the importance of uncertainty, risks, and resilience. Researchers study such diverse topics as climate change impacts and adaptation, valuation and management of ecosystem services, urbanization processes and challenges, and sustainable agricultural systems. We work with decision makers to transform knowledge into action. Partnering with investigators from Clark's Graduate School of Geography and Department of International Development, Community and Environment (IDCE), this core research theme represents one of the largest and most diverse areas of research at the Institute, and one in which large, multi-institutional projects have been successful. Funding for work in this area comes from federal and regional agencies and foundations.

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

Principal Investigator: Robert J. Johnston

Funding Agency: Australia 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 non-market 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: (i) by demonstrating quantitative analyses to support a range of decisions about NMV methods; (ii) by developing heuristics about when particular methodological choices are more likely to be preferred; and (iii) by assisting decision makers to think through these decisions in a more sophisticated and complete way.

## 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 bring new insights to bear 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.

## 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 the states of 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 outcomes (e.g., facility siting, local seafood production, economic impacts, environmental impacts) resulting from 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.

## Linking Coastal Adaption Portfolios to Salt Marsh Resilience and Ecosystem Service Values

Principal Investigators: Robert J. Johnston and Dana Marie Bauer  
Funding Agency: National Oceanic and Atmospheric Administration

This project is an international and interdisciplinary collaboration led by Marsh Institute researchers, with collaborators at the Virginia Institute of Marine Sciences and Monash University in Melbourne, Australia. Tidal marshes are one of the most common natural features that protect the coast from flooding and storms, and are frequently promoted for their ability to support coastal resilience and valued ecosystem services. However, marsh resilience depends on the complex interplay of natural dynamics and human actions. The preservation of marsh transgression zones—undeveloped coastal areas that allow marshes to migrate inland—is among the most critical of these actions. The effect of these zones depends on uncertain sea-level rise and natural dynamics, which determine how, when and where marshes migrate. These uncertainties imply that diversified portfolios of adaptation actions (e.g., preserving different types of transgression zones in different areas) are best able to ensure the resilience of marsh areas and resulting social values. This project develops tools that address a central coastal adaptation question: Considering the influence of sea-level rise and other uncertain factors, how can information

on biophysical dynamics and economic benefits and costs be coordinated to identify optimal, diversified portfolios of adaptation actions that best sustain marsh resilience and ecosystem service values? The project develops and illustrates the methods and resulting insights, using data from multiple Long Term Ecological Research (LTER) sites.

### **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 next-generation approach to SP valuation, Free-form Choice Experiments (FCEs). FCEs restructure the way that WTP is elicited and estimated, hybridizing traditional survey methods with online labor pool survey techniques and Bayesian econometrics. 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.

### **Multi-scale Coupled Natural Human System Dynamics of Nitrogen in Residential Landscapes**

Principal Investigator: Robert J. Johnston  
Funding Agency: National Science Foundation

This \$1.6 million project is a multi-year, interdisciplinary partnership among Clark University, the City University of New York, Cornell University, the U.S. Forest Service Northern Research Station, the University of North Carolina, Florida Atlantic University, the University of Rhode Island, and others. Urban, suburban and exurban ecosystems are increasing in area across the United States. There is significant concern about the environmental performance of these ecosystems, especially the extent to which they export nutrients to receiving waters, and how this net export is related to human behavior. Challenges are especially evident in the management of residential landscapes dominated by grass lawns. This project applies social science theories related to institutional and behavioral change, along with formal economic models of household behavior, to address questions about human decision making regarding the management of residential ecosystems at multiple scales (parcel, neighborhood, watershed, and municipality). These investigations are formally predicated on explicit results from biophysical studies of nitrogen

and water fluxes. The study addresses questions about how flows of information between biophysical and social science domains, either alone or in combination with policy changes, can promote or constrain the adoption and effectiveness of measures to improve the environmental performance of urban ecosystems at multiple scales.

### **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. 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 cost-efficiency 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, cost-effective 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.

### **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 both pollination services and the impacts of pesticide exposure on such services. They also differ in their willingness to adjust management practices to address these impacts, and these differences likely depend on the particular cropscape within which the grower operates. This research project will first develop an integrated pollinator-pesticide cropscape typology that places each county in the continental U.S. along a pollinator risk-reward gradient. The research will then conduct grower surveys in select cropscares to answer the following questions: (i) How aware are growers of the different pathways through which pollinators are exposed to pesticides? (ii) 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 or pesticide abatement, warranted? (iii) How do differences among growers and crops 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 non-targeted insects vulnerable to their effects. Specifically, neonics have been implicated as a factor in sudden die-offs of managed honeybee hives and long term declines in native bee populations. Thus, farmers growing pollinator-dependent 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 \$3.6 million, 5-year 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 Assistant Director Dana Bauer is leading the economic analysis of grower preferences, profitability, and decision making.

### Conserving Small Natural Features with Large Ecosystem Functions in Urbanizing Landscapes

Principal Investigator: Dana Marie Bauer  
Funding Agency: National Science Foundation

Many landscapes have small natural features whose importance for biodiversity or ecosystem services belies their small size. Management challenges for these areas include: uncertainties over their location and contributions to ecosystem services; tensions between private property rights and public rights to environmental protection; and the spatial mismatch between the broad, regional accrual of beneficial services and the concentrated, local costs of protection. Conservation strategies are undermined by limited scientific knowledge, especially of mechanisms that link ecological and social processes. In the forested landscapes of the northeastern U.S., small, seasonally inundated wetlands (vernal pools) emerge as an excellent model system to study the dynamics of small natural feature management. This project brings together a team of ecologists and economists from multiple sub-disciplines and institutions (Clark University, University of Maine, and Bowdoin

College) to: (1) explore the biophysical and socioeconomic components of one type of small natural feature, vernal pools, as a coupled-systems model for management of these features; (2) improve strategies for conserving vernal pools and other small natural features with large significance; and (3) share results with local and state-level stakeholders and policy makers.

### Promoting Sustainable Consumption Research and Action

Principal Investigators: Halina Brown and Philip Vergragt

Marsh Institute researchers Halina Brown and Philip Vergragt 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 (virtual) 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 conference was attended by 350 participants from more than a dozen countries.





## RESEARCH TO PROMOTE WORLDWIDE FOOD SECURITY

A changing climate, population growth, natural hazards, regional conflicts, and degradation of ecosystem services are among the changes that threaten food security in many regions across the globe. These threats are particularly severe in the developing world. George Perkins Marsh Institute researchers are at the forefront of efforts to help ensure food security worldwide. Edward Carr and others at the Humanitarian Response and Development Lab (HURDL) coordinate with partners such as the World Bank, USAID, and the Red Cross Climate Center to promote climate-smart agriculture in Africa. Marsh Institute researcher Lyndon Estes's work investigates the drivers and impacts of agricultural change, with a particular focus on sub-Saharan Africa. His recent work includes the development of sensor networks to understand changing rainfall patterns and relationships to farmers' planting and harvesting decisions. Other types of threats to food security result from the agricultural use of pesticides and other chemicals, with both acute and chronic effects on agro-ecosystem services. For example, Marsh Institute Assistant Director Dana Bauer is working with multi-disciplinary teams to evaluate tradeoffs between pest management and pollinator preservation in U.S. agriculture. Through these and other projects, Marsh Institute researchers are helping to ensure the resilience of the agricultural systems upon which human societies depend.

### 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 Indiana University, researchers in this project will integrate physical models of hydrological and agricultural dynamics with real-time environmental data obtained from previously developed, novel, cellular-based environmental sensing pods and real-time reports of farmer decision making submitted via cell phones. The research addresses three critical research 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 large-scale, smallholder-based 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 crowd-sourcing, in situ environmental sensing, and earth observing satellites to achieve three main objectives: (1) identify patterns of cropland change in smallholder farms; (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, a bellwether for regional agricultural development that has seen recent maize yield increases and farmland expansion.

### 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 flows and 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. Clark 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 a novel integrative framework that merges data, models, and knowledge of drought risk and crop production, their interactions with the dynamics of trade-based and aid-based 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?

### 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 / 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. Characterizing these production systems is crucial for decision makers who manage land tenure systems, improve monitoring, and design conservation strategies within the context of global commodity markets. 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.

### Engaging Students in Science for International Decision Making

Principal Investigator: Elisabeth Gilmore  
Funding Agency: National Science Foundation

Addressing global environmental issues involves working at the intersection of science and decision making. Graduate students and early career researchers who engage in environmental research, however, have few meaningful opportunities within academia to gain the knowledge and training on how their research can be employed for social innovation and collective impacts. This project



Rachael Corcoran-Adams '20 performs research in Chicopee, Mass.

provides an innovative and immersive three-part experience for students on communicating science for decision making through student-led presentations and outreach at a meeting on international environmental issues. First, a 3-day university-based workshop will convene students from multiple institutions and provide intensive training by experts in environmental negotiations and science policy. Students will also work together to develop team presentations on their science research for delivery at a decision-making body. Second, at the UN Framework Convention Conference of the Parties (COP25) in Santiago, Chile, the students will present at an official event for the delegates and an event for the public, conduct media outreach, and participate in daily debriefs led by faculty to link the training at the workshop to the COP agenda. Finally, the students will develop materials stemming from their presentation and experience, such as blogs, press releases and reports. By coupling training and authentic, real world engagement, students will learn how to navigate environmental issues in decision making, gain intercultural and diplomacy skills, and build professional networks.

### **ILTER/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 (ILTER) site is developing a predictive understanding of the response of a linked watershed-marsh-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 rise, 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, marsh-estuarine geomorphology and biogeochemistry? Cross-system comparisons with other LTERs along gradients of temperature, species composition, tidal range, and sediment supply will further our understanding of long-term change in coastal ecosystems.

### **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 substantial 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.

### **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 Investigator: John Rogan and Deborah Martin  
Funding Agency: USDA Forest Service/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.

### FCE III — Coastal Oligotrophic Ecosystems Research

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

The Florida Coastal Everglades (FCE) Long-Term Ecological Research (LTER) site seeks to understand how global climate change and shifting approaches to water management affects the Florida Everglades and the 6 million residents of the region. By conducting extended-duration research in freshwater wetlands, mangrove swamps, and shallow seagrass communities of Florida Bay, the FCE LTER employs long-term datasets to determine how the amount and quality of fresh water flowing through the Everglades influences ecological processes in the coastal zone. Coupled socio-economic studies reveal how decisions about Everglades restoration influence—and are influenced by—the human history of dependence on local natural resources. This project recognizes the importance of water in the sociopolitical environment, and addresses how and why land and water use in South Florida has changed. Specifically, this project identifies the sources of sociopolitical conflicts over freshwater distribution and evaluates how solutions that improve inflows to the Everglades mediate the effects of sea-level rise on freshwater sustainability in the coastal zone.

### Urban Resilience to Extreme Weather-related Events

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

Urban areas are vulnerable to extreme weather-related events because of their location, high concentration of people, and increasingly complex and interdependent infrastructure. Recent disasters demonstrate not just failures in built infrastructure, but also the inadequacy of institutions, resources, and information systems to prepare for and respond to events of this magnitude. This interdisciplinary project will develop a diverse suite of new methods and tools to assess how infrastructure can be more resilient, provide ecosystem services, improve social well-being, and exploit new technologies in ways that benefit all segments of urban populations. The primary research questions are how do social, ecological, and technological systems (SETS) interact to generate vulnerability or resilience to extreme weather-related events, and how can urban SETS dynamics be guided along more resilient, equitable, and sustainable trajectories? Specifically, this project will analyze the spatial structure and land cover components of vulnerability to climate-driven extreme events in Miami, Florida

and comparatively across other urban sites, and entails particular attention to spatially differentiated patterns of urban exposure, sensitivity and adaptive capacity in the face of extreme events such as hurricanes, floods and droughts.

### 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).

## TRAINING RESEARCHERS AT CLARK UNIVERSITY

Recent collaborative efforts between the George Perkins Marsh Institute and the Office of Sponsored Programs and Research have provided workshops and training to enhance research productivity and impact across the university. During 2020, Marsh Institute Director Robert Johnston coordinated with Associate Provost and Dean of Research Yuko Aoyama on a workshop to enhance grant-writing skills across the university, "Secrets of Research Proposal Success: What Top Grant-Writers Know," following up on similar successful efforts in 2018 and 2019. As Co-Chair of the University's Institutional Review Board (IRB), Johnston also worked with researchers to ensure that their work met rigorous standards to protect the rights and safety of human subjects. During 2020, Johnston led the development of a new online submission and review platform for human subjects research proposals at Clark University. Through these and other efforts, the Marsh Institute works to improve research success across multiple disciplines and departments.

# EARTH SYSTEM SCIENCE



*Geography Professor Karen Frey conducted research aboard the Sir Wilfrid Laurier in the Arctic's Chukchi Sea last summer.*

Centered in expertise at Clark University's internationally recognized Graduate School of Geography, Earth System Science research at the George Perkins Marsh Institute examines the structure and function of the Earth's lithosphere, atmosphere, hydrosphere, cryosphere, and biosphere, and how these systems interact. Earth System Science research studies the connections among earth system components that are at the heart of such issues as carbon cycling, climate change, water scarcity, and the loss of biological diversity, with an emphasis on understanding and predicting global environmental changes. Of particular relevance to the Institute are the causes and consequences of global climate change. Work in this area is supported by major grants from the National Science Foundation, the National Aeronautics and Space Administration, the National Geographic Society, and the Nature Conservancy.

## **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 in the timing of spring sea ice retreat or delays in fall sea ice formation. Recent observations of reduced sea ice extent and duration and seawater warming 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 direct evidence of negative impacts on ice-dependent species such as walrus. Some distribution shifts may be driven by changes in lower trophic level productivity that directly cascade into higher trophic levels. Spatial changes in carbon production and export to the sediments—as indicated by macrofaunal community composition and biomass, changing sediment grain size, and range extensions for lower trophic levels—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 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 focus on the following research questions: (1) Will an earlier sea ice retreat and changes in seawater hydrographic properties (salinity, temperature, and nutrients) 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?

### **Albedo Impacts of Avoided Forest Conversion, Afforestation, and Increased Deciduousness**

Principal Investigator: Christopher A. Williams  
Funding Agency: 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 Canada. One of the major improvements relative to prior work is to include more detailed and quantitative assessment of the albedo offsets to potential climate benefits of forest pathways. The project will deliver quantitative assessments of the albedo-induced radiative forcing and associated CO<sub>2</sub> equivalent emissions that would be caused by the avoidance of forest conversion (deforestation), by expanded forest cover (afforestation), or by actively increasing the deciduous component of forest species composition in select regions across Canada.

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

Principal Investigator: Christopher A. Williams  
Funding Agency: Doris Duke Foundation/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.



## **HELPING GOVERNMENT AGENCIES INCORPORATE ECOSYSTEM SERVICES INTO DECISION MAKING**

Marsh Institute Director Robert Johnston has engaged in a number of collaborative efforts to inform the ways that US federal agencies manage and account for ecosystem services (the goods and services provided by nature). Johnston is Co-Chair of the Ecosystem Sciences and Management Working Group (ESMWG) for the NOAA Science Advisory Board (SAB), a group that provides scientific advice and broad direction to the SAB regarding NOAA's ecosystem related programs. He is also a member of the steering committee of a US EPA effort (led by Paul Ringold at EPA) seeking to improve the agency's ecological monitoring programs by helping them identify and measure relevant indicators of final ecosystem goods and services. Johnston was part of the interdisciplinary team that created the Federal Resource Management and Ecosystem Services Guidebook and co-authored Best Practices for Integrating Ecosystem Services into Federal Resource Management, two guidance documents intended to help federal agencies respond to rules and regulations on ecosystem services and federal decision making. He has pioneered benefit transfer methods now used worldwide to estimate the economic benefits of ecosystem services improvements. Johnston's work in this area is supported by multiple large federal and international grants, including a recent \$5,000,000 grant from the USDA Agriculture and Food Research Initiative (AFRI) on advancing the use of meta-analysis for ecosystem service benefit transfer.

## 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 CO<sub>2</sub> equivalent emissions that would be caused by the avoidance of forest conversion (deforestation), 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 model-based 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. These surface flux priors should represent realistic spatial and temporal errors in the biological fluxes emerging from parameter uncertainty, be unbiased, and encompass the truth. 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?

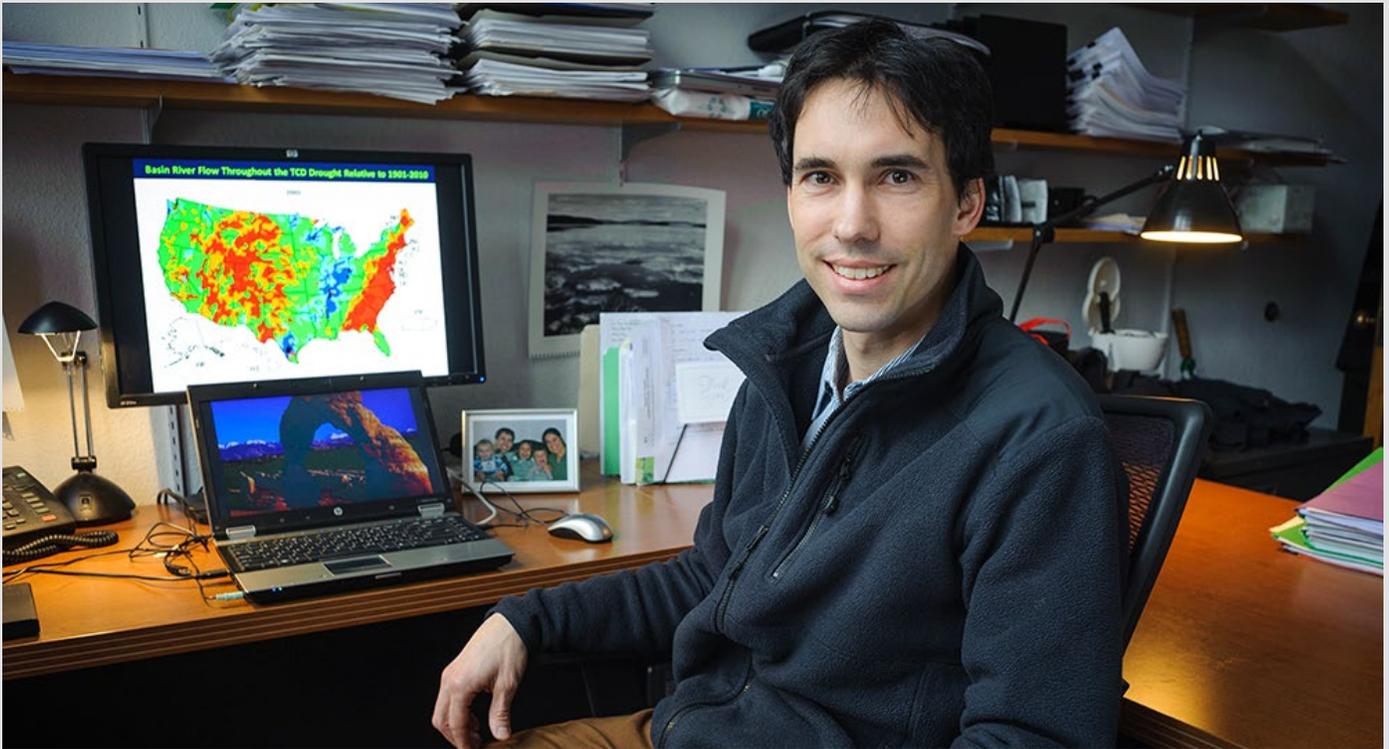
Principal Investigator: Deborah Woodcock  
Funding Agency: National Geographic Society

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 volcanoclastic 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 co-occur; 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.



Woman in rural community

## RESEARCH TO INFORM GLOBAL CLIMATE CHANGE ADAPTATION



Global climate change affects millions of people world-wide through increased intensity and frequency of droughts, floods, pest infestations, and habitat destruction and degradation. George Perkins Marsh Institute researchers are at the forefront of science and policy efforts to inform climate change mitigation, adaptation, and long-term resilience. Edward Carr and Robert Goble are evaluating existing climate information services (CIS) programs in Africa with the goal of increasing the efficiency and effectiveness of future investments in CIS delivery, and ultimately increasing the number of users of CIS who benefit through livelihood practices. Karen Frey is determining the impact of thinning and retreating sea ice cover on biological productivity and biogeochemical cycling in the Pacific Arctic region. Robert Johnston is comparing the vulnerability of salt marshes to sea-level rise in three Atlantic coastal sites that vary with respect to sediment supply, tidal range, and human impacts in order to understand how potential adaptations may influence marsh vulnerability, associated economic benefits and costs, and practical management decisions. Gil Pontius is exploring how internal feedbacks within the Gulf of Maine marsh-estuary ecosystem influence the response of geomorphology, biogeochemistry, and food webs to three major drivers: climate, sea-level rise, and urbanization of the watershed. Rinku Roy Chowdhury is analyzing the spatial structure and land cover components of vulnerability to climate-driven extreme events (e.g., hurricanes), characterizing how communities in Miami and other urban sites exhibit differential vulnerability to extreme events, and their resilience or adaptive capacity in the face of such events. Christopher Williams is investigating uncertainty in current models of carbon dioxide and methane sources and sinks to produce more accurate and precise estimates that will enable the more accurate prediction of a future climate and improve climate change mitigation and adaptation. Through these and other projects, Marsh Institute researchers are helping to ensure sustainable natural, human, and engineered systems in a world threatened by a rapidly changing climate.



## INSTITUTIONS AND HUMAN DEVELOPMENT

*Bridge construction on the road between Puerto Cabezas/Bilwi in Nicaragua and the border with Honduras. Roads on either side of the bridge are seasonally impassible. (Photo by Laura Sauls)*

Interactions among the environments in which we live, resource governance, and the role of public and private institutions have important effects on human health, development, and welfare. Institutions and governance determine whether and how people benefit from natural resources and the resilience of local populations to global change and regional upheavals. They are also critical to the opportunities available to different groups within society. Partnering with investigators from the Department of International Development, Community and Environment (IDCE), Graduate School of Geography, and the Department of Economics, the Marsh Institute under-takes research to promote improved human condition, with particular emphasis on challenges related to disadvantaged populations, refugees, urban areas, resource extraction and governance, and social and environmental justice. Much of this work coordinates closely with community partners to promote positive social change.

### Background Research in Support of NYDF Assessment Report 2020

**Principal Investigator:** Denise Humphreys Bebbington  
**Funding Agency:** Climate Focus/ New York Declaration on Forests

The New York Declaration on Forests (NYDF) is a voluntary and non-binding international declaration calling for action to halt global forest loss. Since it was first endorsed at the United Nations Climate Summit in 2014, support for the NYDF has grown to include national and subnational governments, multinational companies, indigenous organizations, and nongovernmental organizations around the world. NYDF produces an annual Assessment Report to monitor progress towards its ten goals. This project will conduct research on progress related to Goals 3&4, in preparation of the NYDF Assessment Report 2020.

### Preparation of Land Sector Policy Papers

**Principal Investigator:** Cynthia Caron  
**Funding Agency:** Global Land Alliance/Millennium Challenge Corporation

The Millennium Challenge Corporation (MCC) works with developing countries to promote sustainable economic growth and reduce poverty. The objectives of MCC's land investments include improved land tenure security and access to land for investment purposes to boost economic activity and growth, as well as to support improved use and productivity of land. In an effort to support decisions on land policy and legal reform actions in Sri

Lanka, this project will investigate the benefits of co-ownership of permits/grants and joint titling of land between spouses, along with inheritance reform, in order to increase land productivity, reduce poverty, and promote gender equity. The research will address the following questions: (1) How will greater gender equity in land rights and inheritance of land benefit the economy and social stability in rural areas? (2) Does the evidence of effects on the economy support a Government of Sri Lanka initiative for changes in policy, law, and implementation?

### Migration, Transformation and Sustainability

**Principal Investigators:** Edward Carr and Anita Fabos

**Funding Agency:** National Science Foundation/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 migration-sustainability 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.

### Assessment and Scoping of Infrastructure and Extractive Industries in Relation to Deforestation — Part 2

**Principal Investigators:** Denise Humphreys Bebbington, Anthony Bebbington, and John Rogan

**Funding Agency:** Climate and Land Use Alliance (CLUA)

Large-scale infrastructure and extractive industry projects have attracted significant private and public investment, with direct and indirect synergies between them. However, while the effect of roads on deforestation has been widely studied, the extent to which extractive industry affects forest cover and forest-dependent livelihoods is less clear. Although the actual footprint of operations is modest in absolute terms, the footprint of pollutant-based externalities can be far larger. In addition, the drivers of these different processes are multiple and complex. With a focus on three regions (Brazil, Mexico/Central America, and Indonesia), this project: (1) describes the recent geography of infrastructural and extractive industry investments; (2) assesses the current state of knowledge regarding the impacts of these investments on forest cover and quality, and the rights, organizations and livelihoods of forest-dependent communities; (3) examines the work different organizations are already doing on the relationships among infrastructure, extractives and forests, including what their successes and failures have been with different types of strategy; and (4) identifies feasible strategies for CLUA.

### Generative Urbanization in Emerging Africa? The Case of Konza Techno City

**Principal Investigator:** James Murphy

**Funding Agency:** Regional Studies Association

Africa is experiencing an urban transition that raises significant questions as to whether its economies are being transformed structurally. In Kenya, the prospects seem particularly high as the country has experienced steady growth and urbanization since the early 2000s. In response, the country's leaders are constructing Konza Technopolis, a "smart" urban development project that aims to establish industrial clusters in the information-communication technology (ICT), life sciences, and engineering sectors that will foster innovation, attract foreign direct investment, and create knowledge spillovers and other positive externalities to position Kenya favorably in high-tech industries globally. This study is examining the design and on-going development of Konza in order to assess whether such a project might spur industrial transformation in Kenya. The research will determine whether outcomes such as innovation, labor market development,

## HUMANITARIAN RESPONSE AND DEVELOPMENT LAB



The Humanitarian Response and Development Lab (HURDL) is a development and humanitarian assistance research and implementation lab within the George Perkins Marsh Institute at Clark University. 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, Jozefina Lantz joined HURDL to conduct research related to migration dimensions of transformations to sustainability.

industrial diversification, and urban sustainability are possible and what challenges need to be addressed to ensure Konza's success. The research will advance geographical conceptualizations of the links between urbanization and development and provide key insights for policy makers and planners.

### Community for Center Change Evaluation Project

**Principal Investigator:** Margaret Post

**Funding Agency:** JPB Foundation/Innovation Network

This project will provide an outcomes-based evaluation of Community for Center Changes four-year economic justice initiative. This initiative aims to build national and local support for economic justice issues by increasing the salience of poverty and economic justice, supporting breakthroughs, and building movement. The evaluation includes: a set of 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.

### 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 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/TCB

The Community Builders (TCB) is a nonprofit developer, owner and manager of affordable and mixed-income housing. Community Life is TCB's 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.

### 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 multi-disciplinary 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-of-school 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-Farquharson 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.

### Shannon Community Safety Initiative: Massachusetts Statewide 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) is a state-wide program designed to reduce youth and gang violence in cities across Massachusetts. The initiative supports regional and multi-disciplinary approaches through the implementation of the Comprehensive Gang Model, an evidence-based and intentional integration of prevention, intervention, suppression, organizational change, and community mobilization strategies. This multidisciplinary approach includes law enforcement initiatives such as hot spot analysis and anti-gang task forces, coordinated reentry programs for young adults and juvenile offenders, and education and employment programs for high-risk youth. As the Statewide Youth Violence Research Partner, investigators Ross and Safford-Farquharson (1) identify emerging best practices in the literature related to youth and gang violence; (2) collaborate with individual Shannon CSI sites; (3) analyze information collected through quarterly reports and produce statewide summary reports and a comprehensive report on the impact of Shannon CSI; and (4) provide training and technical assistance on the Comprehensive Gang Model.

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



The Clark Center for the Study of Natural Resource Extraction and Society ([Extractives@Clark](mailto:Extractives@Clark)), a research center within the George Perkins Marsh Institute, 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 of the implications of their findings for the Alliance’s work. In addition, Bebbington, Humphreys Bebbington, and Rogan (together with Professor Florencia Sangermano, post doctoral researcher Nick Cuba and doctoral student Ben Fash) have 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. This past year, the center housed post-doctoral researchers Nick Cuba and Laura Sauls.



*Nick Cuba, post-doctoral researcher*



*Laura Sauls, post-doctoral researcher*

## STUDENT RESEARCH AND IMPACT

The George Perkins 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. Throughout 2019-20, Marsh Institute grants and endowments supported 40 graduate students, seven undergraduate students, and one post-doctoral fellow.



*HERO Fellows 2020-21: L-R: William Sanders '21, Valeria Chavez '21, Galen Oettel '21, Alvaro Esparza'21, Anna Massinger '22, Nick Geron (PhD student) and Marc Healy (PhD student)*

### GREENING THE GATEWAY CITIES (HERO PROJECT)

Principal Investigators: John Rogan and Deborah Martin  
Funding Agency: John T. O'Connor '78 Endowed Fund for Environmental Studies

Built on 20 years of success, the Human-Environment Regional Observatory—Massachusetts (HERO—MA) program is a unique undergraduate-graduate-faculty collaborative that conducts research on human-environment relationships in Massachusetts. HERO Fellows analyze the causes and consequences of global environmental changes at local scales in faculty-led research projects. Each Fellow is paired with a Clark faculty mentor and other researchers on the HERO team. 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 Clark University O'Connor '78 Fund.

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 high-density neighborhoods in 26 former factory towns by providing trees to residents and planting trees along city streets. In 2020, field research in the Gateway Cities was suspended due to the COVID-19 pandemic. Instead, HERO Fellows planted several species of trees at Clark's Hadwen Arboretum and analyzed previously collected air temperature sensor data. HERO Fellows presented their work at a 2020 (virtual) Stakeholder Summit and will spend the 2020-21 academic year working on individual research projects and present their findings during Clark's Academic Spree Day.

## 2020 ALBERT, NORMA AND HOWARD '77 GELLER ENDOWED RESEARCH AWARDS

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, through these annual awards, to support other Clark undergraduate and graduate students combine research with action that moves society toward sustainability.



**Rachel Corcoran-Adams, BA Geography & IDSC/MS GIS '21, Mentor: Dominik Kulakowski**

### Individual-Based Process Model of Forest Regeneration

Wildfire activity in the western U.S. has increased in severity and frequency, raising concern among scientists and land managers about the long-term resilience of western forests. Post-fire climate is inhibiting post-fire regeneration and leading to an ecosystem conversion from forest to grass-like landscapes. This study will use an individual-based process model parameterized with extensive field data to characterize the interactions among climate change, altered disturbance regimes, post-disturbance regeneration, and forest resilience in the Rocky Mountains.



**Ravi Hanumantha, PhD, ES&P '23, Mentors: Timothy Downs, Karen Frey, and Morgan Ruelle**

### Exploring the Sustainability and Climate-Change Resilience of Water Supply and Wastewater Sanitation in the Mexico City Region

Over 24 million people in Mexico City and the surrounding region face: (a) chronic scarcity of clean water; (b) lack of wastewater sanitation in many neighborhoods; and (c) deteriorating water distribution and wastewater drainage infrastructure. The region is facing high chronic water stress compared to other regions in Mexico and climate change amplifies these threats. This study will develop a water system simulation model to understand the existing water supply and wastewater sanitation systems in the Mexico City Region, and identify ways their resilience can be improved.



**Sarah Lerman-Sinkoff, PhD Geography '23, Mentor: John Rogan**

### Exploring the Use of a Low-Cost Photopaper Tool for Citizen Science Detection of Urban Gas Leaks

Sensors available to detect gas leaks are both too costly and too inaccessible to be used regularly by grassroots climate justice activists. Previous research suggests that a low-cost photopaper tool developed to document hydrogen sulfide pollution could also respond to the sulfur compounds present in commercial natural gas. This study will explore both the scientific and social dimensions of using the photopaper tool in this setting, including engagement with a community partner and the training of citizen scientists to gather data in vulnerable urban neighborhoods.



**Kyle Pecsok, BA Geography/MS GIS '21, Mentor: Dominik Kulakowski**

### Characterizing Change in Initial Post-Fire Regeneration in the Rocky Mountains

Increasing temperatures due to climate change can lead to earlier-onset spring, longer dry seasons, and more severe droughts in western U.S. forests. Post-wildfire regeneration is influenced by disturbance type, pre-disturbance forest stand structure and composition, and post-disturbance climate, though this latter influence is not yet well understood. This study will collect and analyze extensive field data at 21 Rocky Mountain sites to assess how climate has influenced initial density, age and size structure, and rate of post-wildfire regeneration.

## 2019-20 GEORGE PERKINS MARSH INSTITUTE SEMINARS

Each year the Marsh Institute sponsors formal lectures and seminars that expose faculty and students to contemporary research and also provide a foundation for future research collaborations. These include lectures conducted as part of the George Perkins Marsh Institute/Jeanne X. Kasperson Library Seminar Series, as well as periodic Marsh Distinguished Lectures. The Institute also coordinates multiple endowed lecture series. These include the Albert, Norma and Howard '77 Geller Endowed Lecture Series, and the Debra I. and Jeffrey A. Geller Endowed Lecture Series. Both of these endowments support lectures related to the environment and sustainability.



**"Cracking Appalachia:  
A Political-Industrial Ecology  
Perspective"**

Co-sponsored with the  
Graduate School of Geography

**JENNIFER BAKA**

Assistant Professor, Department of Geography,  
Pennsylvania State University



**"Predicting High-Magnitude,  
Low-Frequency Crop Losses Using  
Machine Learning"**

Debra I. and Jeffrey A. Geller  
Endowed Lecture

**MICHAEL MANN**

Associate Professor, Department of Geography,  
George Washington University



**"Feminist Political Ecology  
of Land-Water Enclosures in  
Coastal Tanzania"**

Co-sponsored with the  
Graduate School of Geography

**YOUJIN CHUNG**

Assistant Professor, Graduate School of Geography,  
Clark University



**"Protection of Drinking Water Supply  
Sources: Challenges, Successes,  
and Lessons Learned"**

**CHI HO SHAM**

Vice President and Chief Scientist,  
Eastern Research Group, Inc.



**"Secrets of Research Proposal  
Success: What Top Grant-Writers  
Know"**

Co-sponsored with the Office of Sponsored  
Programs and Research

**ROBERT J. JOHNSTON**

Director, George Perkins Marsh Institute,  
Clark University



**"Scientific Integrity in the Just  
Preservation of Nature"**

Debra I. and Jeffrey A. Geller  
Endowed Lecture

**ADRIAN TREVES**

Professor, Nelson Institute of Environmental Studies,  
University of Wisconsin-Madison



Photography © Lu Ann Pacenka

### Jeanne X. Kasperson Research Library

One of the integral parts of the Marsh Institute, 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 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 is 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 crucial research support for university researchers; undergraduate and graduate students; visiting foreign 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. The staff provide exceptional and personalized research assistance.



BJ Perkins  
Director

### 2019-20 George Perkins Marsh Institute Steering Committee

Steering Committee members are chosen to represent the diversity of the 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.

#### **Anthony Bebbington**

Higgins Professor of Environment and Society  
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**

Assistant Professor,  
Graduate School of Geography

#### **Karen Frey**

Associate Professor,  
Graduate School of Geography

#### **Robert Goble**

Research Professor, George  
Perkins Marsh Institute

#### **Deborah Martin**

Professor and Director,  
Graduate School of Geography

#### **Laurie Ross**

Professor of Community  
Development and Planning,  
International Development,  
Community, and Environment

#### **Rinku Roy Chowdhury**

Associate Professor,  
Graduate School of Geography

#### **Christopher Williams**

Associate 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

## PANELS, AWARDS AND ACCOMPLISHMENTS

George Perkins Marsh Institute researchers are internationally recognized for their expertise and are called upon frequently to serve on scientific boards, committees and panels. Authored and edited publications advance the state-of-the-science in many fields, and each year the contributions of our faculty and staff are recognized by national and international awards.

### Advisory Boards and Committees

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 national and international policy guidance. Examples during 2019-20 included:

**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.

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

**Halina Brown** is a chairperson of Newton Citizens Commission on Energy, which released its *Citizens Climate Action Plan* for achieving carbon neutrality by 2050.

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

**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.

**Karen Frey** serves as Vice Chair of the Marine Working Group of the International Arctic Science Committee (IASC). Only two U.S. scientists were appointed to this prestigious group.

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

**Dale Hattis** is an ad hoc member of the U.S. Environmental Protection Agency's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP).

**Denise Humphreys Bebbington** serves on the Advisory Council of the CASA Socio-Environmental Fund.

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

**Robert Johnston** is on the Fulbright U.S. Student Program National Screening Committee.

**Robert Johnston** is on the Sacramento-San Joaquin Delta Social Science Task Force.

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

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

**Robert Johnston** serves as editor of *Resource and Energy Economics*.

**Robert Johnston** 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 since 1925.

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

**Robert (Gil) Pontius Jr.** was named to the Scientific Advisory Committee of MapBiomass.

**Rinku Roy Chowdhury** is a coordinating lead author of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment Report.

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

**Rinku Roy Chowdhury** is a member of the International Long-Term Ecological Research (LTER) Committee.

**Philip Vergragt** is a member of the Steering Group of KAN SSCP, the Future Earth Knowledge Action Network on Systems of Sustainable Consumption and Production and a co-lead of the Working Group on Communication for Sustainable Consumption.

**Christopher Williams** is a member of the North American Carbon Program's (NACP) Science Leadership Group, a multi-disciplinary research program established to study how carbon cycles through ecosystems, oceans and the atmosphere.

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

**Junfu Zhang** is serving a three-year term as President of the Chinese Economics Society.

## Publications

Each year researchers at the George Perkins 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. Updated lists of publications and curricula vitae can be found on the Marsh Institute research appointments website, <http://www.clarku.edu/departments/marsh/faculty/index.cfm>. The following are a few highlights:

**Anthony Bebbington, Denise Humphreys Bebbington, Laura Sauls, John Rogan, Kimberly Johnson** and colleagues published "Resource extraction and infrastructure threaten forest cover and community rights" in *Proceedings of the National Academy of Sciences*.

**Halina Brown** published the article "The US economy is reliant on consumer spending — can it survive a pandemic?" in *The Conversation*.

**Arthur Elmes (PhD, Geography)** led a multi-institution review paper "Accounting for training data error in machine learning applied to earth observations" published in *Remote Sensing*. Co-authors include Ronald Eastman, Lyndon Estes, Robert (Gil) Pontius, John Rogan, and Su Ye (PhD, Geography).

**Karen Frey** and colleagues at the University of Maryland Center for Environmental Science, Université Laval, and the Scottish Association for Marine Science published "Seasonal and latitudinal variations in sea ice algae deposition in the Northern Bering and Chukchi Seas determined by algal biomarkers" in *PLOS ONE*.

**Robert Johnston and Dana Bauer** published "Using meta-analysis for large-scale ecosystem service valuation: progress, prospects and challenges" in *Agricultural and Resource Economics Review*.

**William Lynn** and colleagues published "Don't blame cats for destroying wildlife – shaky logic is leading to moral panic" in *The Conversation*.

**Robert (Gil) Pontius Jr.** and colleagues published "Intensity analysis to communicate land change during three time intervals in two regions of Quanzhou City, China" in *GISCIENCE*.

**Laurie Ross, Yelena Ogneva-Himmelberger**, and colleague Casey Starr published "The use of Geographic Information Systems for real-time monitoring of comprehensive community initiatives" in *Justice Research and Policy*.

**Rinku Roy Chowdhury** and colleagues published "Pervasive human-driven decline of life on Earth points to the need for transformative change" in *Science*.

**Philip Vergragt** and colleagues published "Communicating sustainable consumption" in the *Handbook of Sustainability Communication*.

**Deborah Woodcock** and colleague Herbert Meyer published "The Piedra Chamana fossil woods and leaves: a record of the vegetation and palaeoenvironment of the Neotropics during the late middle Eocene" in *Annals of Botany*.

## Awards and Recognitions

National and international awards reflect the contributions, expertise and reputation of Marsh Institute scientists. Recent national and international awards received by Marsh researchers include the following:

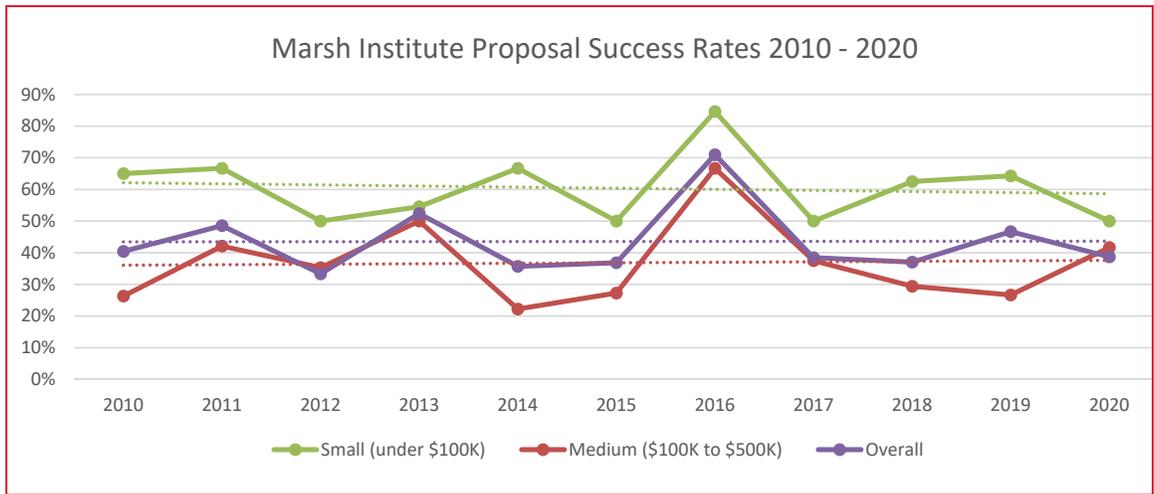
**Thomas Bilintoh** (PhD, Geography) was awarded second place for the poster "Methods to compare cases concerning categorical transitions during various time intervals" at 2020 meeting of the American Association of Geographers.

**Karen Frey** was an NSF-invited organizing committee member of the Polar Technology Conference and co-authored the associated Meeting Report.

**Robert (Gil) Pontius Jr.** gave an invited keynote address and workshop to the International Conference on GIS in Mérida Mexico.

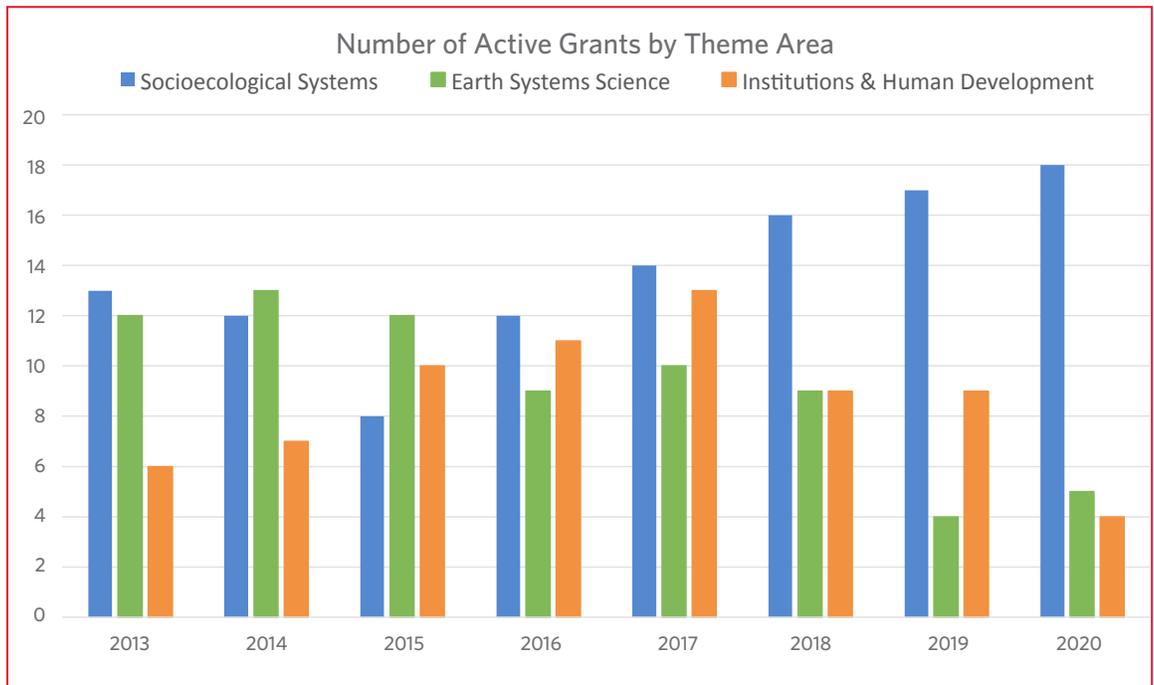
**Laurie Ross** received the inaugural Youth Champion Award at an appreciation breakfast at the Harrington Boys and Girls Club in Worcester.

**Philip Vergragt** delivered a (virtual) keynote for the International Sustainable Development Research Society (ISDRS) Conference in Budapest, July 15, 2020, "Sustainable Consumption in times of Covid-19."



### Grants and Revenues

A significant 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 Department of Economics, and the International Development, Community, and Environment Department. The institute's overall proposal success rate averages around 45%, with higher average success rates for small grants (under \$100K) and a recent uptick in the success rate for medium grants (\$100K to \$500K). The grant portfolio shows a steady increase in the number of active grants in the Socioecological Systems theme area, due in part to the addition of larger, multi-year projects. As of July 2020 the Institute maintained approximately \$10.8 million in current grants, covering 36 active projects. Ten of these are components of large-scale, multi-institutional research projects each exceeding \$1 million in total funding. During FY2020, the Marsh Institute was awarded \$1,793,513 million in new grants, with an average size of \$149,459 per grant.



## Service for the Greater Good

The George Perkins Marsh Institute is dedicated to research of consequence that engages with partners to promote sustainability and social welfare. Among the Institute's primary goals is the dissemination of knowledge through workshops, seminars and other sponsored events. In addition, Marsh Institute researchers serve on numerous boards and committees for regional, national and international organizations including science advisory panels, journal editorships, boards of directors, and other principal roles. Through service to these groups, we contribute to scholarly pursuit and public service. For more information on our researchers and events, visit: [clarku.edu/centers/marsh-institute](http://clarku.edu/centers/marsh-institute).

## 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.

## Want to know more?

Information on these and other activities at the Marsh Institute may be found on our website or feel free to contact us.

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