

George Perkins Marsh Institute

**Highlights, Accomplishments,
and Impacts**

2022 Annual Report



Promoting Sustainable Environments for the Public Good

Informing Solutions to Global Change

On the Front Cover:

Marsh Institute researcher Florencia Sangermano (Assistant Professor of Geography) strapping an audio recorder onto a tree. Sangermano is monitoring the soundscapes across Central Massachusetts forests, recording everything from chirping birds to traffic to rainfall, in order to gauge the health of these ecosystems and determine the impact that humans and climate change are having on them.

DIRECTOR'S STATEMENT

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

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

Human actions are causing profound transformations of integrated systems at unprecedented speeds and scales. Through complex feedback processes, these changes pose direct threats to the sustainability of natural and social systems, and lead to deep uncertainties for decision-making. Building on Clark University's legacy of leadership in geography, economics, development and urban studies, geospatial analytics, and natural resource governance, the institute provides the translational knowledge and integrative collaborations needed to understand and sustain these systems. We promote collaborative, evidence-based research that challenges traditional disciplinary boundaries to address some of the most pressing issues facing today's world.

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

The Marsh Institute is one of the most productive hubs for research and funding at Clark University, regularly generating approximately half of all external research funds received by the university. We seek equitable and just solutions to real-world problems and work directly with practitioners to implement those solutions from local to global scales. External support for these and other institute activities comes from federal, state, local and international grants, private donations, foundations, and other sources.

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

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

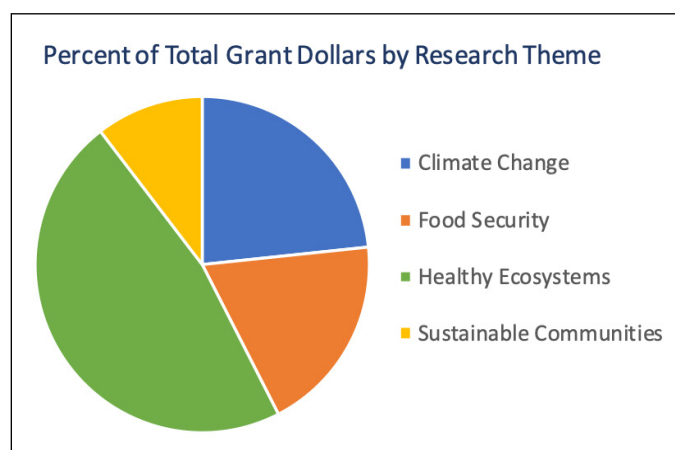
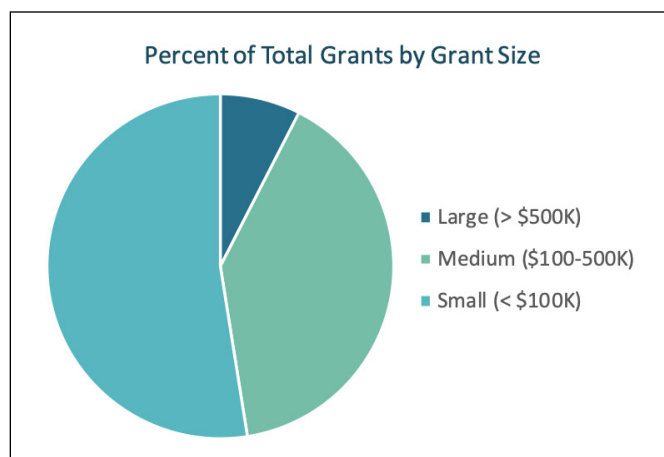
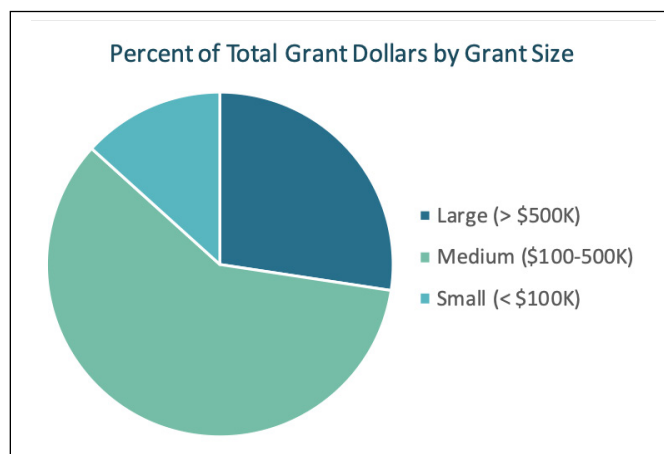
Among the facilities, offices, and centers that comprise the Marsh Institute is the Jeanne X. Kasperson Research Library, whose holdings include one of the most extensive research collections in North America on risks, hazards, and global environmental change. We are also home to the Humanitarian Response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

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

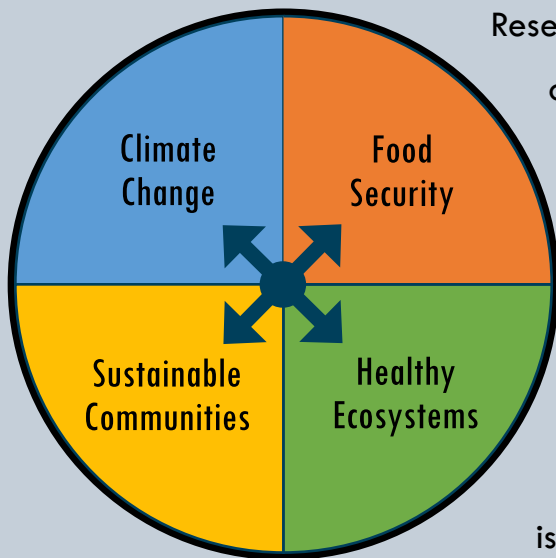
Robert J. Johnston, Director

GRANTS AND REVENUES

A large portion of Clark University's external grant funding is generated by the Marsh Institute, in coordination with our partners in the Graduate School of Geography, the International Development, Community, and Environment (IDCE) Department, and the Department of Economics, among others. This past year, the institute maintained approximately **\$10.6 million in current grants**, covering **39 active projects**: 20 grants for small (under \$100,000) projects, 16 grants for medium (\$100,000 - \$500,000) projects, and 3 for large (over \$500,000) projects. Seven grants are components of large-scale, multi-institutional research projects, each exceeding \$1 million in total funding. During FY2022, the institute was awarded \$3,977,260 in new grants, with an average size of \$180,785 per grant. The institute's overall proposal success rate was around 69%, with higher success rates for small (94%) and medium (56%) grants.



Broken down by research theme, projects related to healthy and viable ecosystems represent 47% of total grant funds, while projects related to climate change impacts and adaptation provide another 23% of grant funds. The largest number of projects are related to sustainable communities and livelihoods.



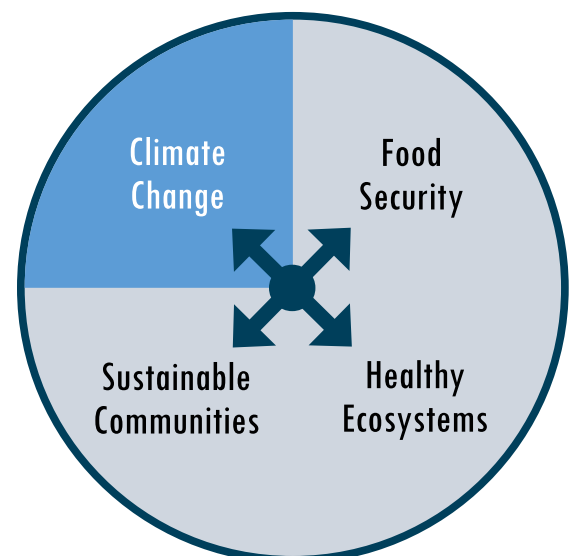
Research at the Marsh Institute addresses some of the most critical issues facing society today. Research topics fall under one or more broad themes related to sustainable natural and human systems: **(1) Climate Change Impacts and Adaptation, (2) Local and Global Food Security, (3) Healthy and Viable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

as with researchers from other institutions around the world. Many projects focus on the analysis of policies and programs that impact the health and well-being of integrated human and natural systems. The scale of projects ranges from local neighborhoods to regional watersheds to whole countries and the entire globe. **New research projects initiated during 2022** address topics such as: mitigating climate change impacts and inequities in Central Mexico, investigating the use of conservation incentives in water-scarce agroecosystems, advancing green infrastructure in the Blackstone Watershed, evaluating the effects of habitat loss on pathogen spillover risk in the Brazilian Atlantic Forest, resource management planning for climate extremes in Hawai'i, understanding impacts of sea ice loss on the Pacific Arctic marine ecosystem, quantifying climate impacts of forest loss in the conterminous U.S., improving delivery of farm extension services in Africa, developing next-generation tools for ecosystem service valuation, and studying how non-profit organizations build community leadership and strengthen democratic processes.

RESEARCH PROJECTS

CLIMATE CHANGE IMPACTS AND ADAPTATION

Global climate change affects every living organism on the planet through cascading effects such as an increased intensity and frequency of droughts, floods, forest fires, pest infestations, and habitat destruction and degradation. Marsh Institute researchers are at the forefront of science and policy efforts to inform climate change mitigation, adaptation, and long-term resilience to sustain ecological systems and human livelihoods. For example, **Tim Downs** and colleagues are combining innovative technologies and stakeholder engagement to co-create research and education capacities that allow for comparing alternative climate/development scenarios in Central Mexico. **Abby Frazier** is collaborating with researchers across the state of Hawai'i to share knowledge and data regarding local and regional drought situations to inform stakeholder actions and policy decisions. **Karen Frey** is quantifying the impact of thinning and retreating sea ice on biological productivity and biogeochemical cycling in the Pacific Arctic. **Robert (Gil) Pontius** is exploring how internal feedbacks within the Gulf of Maine marsh-estuary ecosystem influence resilience and responses to climate change, sea-level rise, and urbanization of the watershed. **Christopher Williams** is working with The Nature Conservancy to develop decision-support tools for evaluating climate change mitigation opportunities from reforestation, avoided deforestation, and improved forest management across the U.S. and Canada. Through these and other projects, Marsh Institute researchers are helping to ensure sustainable natural and human systems in a world threatened by a rapidly changing global climate.



Co-creating Research and Education Capacities to Understand, Visualize, and Mitigate Climate-Change Impact Cascades and Inequities in Central Mexico

Principal Investigators: Timothy Downs (Project PI), Cynthia Caron, Paul Cotnoir, Abby Frazier, Karen Frey, Yelena Ogneva-Himmelberger, Rinku Roy Chowdhury, Morgan Ruelle, and Terassa Ulm Funding Agency: National Science Foundation

In a rapidly urbanizing and climate-changing world, inter-basin water supply megaprojects are on the rise, with energy, greenhouse gas, and water injustice implications. These projects are subject to perverse positive feedbacks such that they increase climate change, and thus increase the water scarcity used to justify them in the first place. This project uses a planned 3-fold-expansion water supply program for Mexico City as the urgent impetus to co-create a new frontier in climate-change impact science, policy analysis and education. Participatory GIS and collaborative System Dynamics Modeling are paired to make impact cascades (i.e., multiple climatic and non-climatic impacts occurring simultaneously and interacting across sectors and regions) and social inequities spatially explicit. Results are then combined with eXtended Reality (XR) technology to visualize and compare alternative climate/development scenarios that diverse stakeholders can inhabit virtually. The project will also co-create research-based courses for U.S. and Mexico-based students, as well as enhance community engagement, to facilitate integration of the research with public education.

Scaling up the Hawai'i Drought Knowledge Exchange

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

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

Drought Early Warning and Response in Hawai'i—Expanding and Enhancing Stakeholder-Driven Drought Products and Services

Principal Investigator: Abby Frazier
Funding Agency: National Oceanic and Atmospheric Administration

The National Integrated Drought Information System (NIDIS) has worked collaboratively to build an important foundation for understanding drought in Hawai'i and U.S.-Affiliated Pacific Islands (USAPI). The Pacific Drought Knowledge Exchange (PDKE) collaborative: (i) brings together relevant agencies and stakeholders for meaningful engagement and collaborations in the Pacific; (ii) explores knowledge co-production with land stewards and resource managers including the delivery of tailored climate data products; (iii) provides easier access to drought and climate information and data sources for a wide range of private, Native Hawaiian, Pacific Islander and agency based stewards and managers; (iv) enhances quality and scope of information available to users; (v) improves capacity for knowledge delivery and technical assistance; and (vi) fosters a more collaborative information transfer environment. This project will develop a formalized, centralized structure for drought research and knowledge exchange designed to support ongoing and future drought related work in Hawai'i and USAPI.

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

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

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

Translating Existing Model Results to Aid in Resource Management Planning for Future Precipitation Extremes in Hawai'i and Southeast Alaska

Principal Investigator: Abby Frazier

Funding Agency: U.S. Geological Survey

The USGS Pacific Islands and Alaska Climate Adaptation Science Centers have supported the development of high-resolution future climate model projections for the steep-gradient watersheds of Hawai'i and Southeast Alaska. However, these model results are currently not accessible to resource managers in user-friendly formats, and no clear descriptions of the data or uncertainty are available. In partnership with the University of Alaska at Fairbanks, University of Hawai'i at Manoa, and other stakeholders, this project will co-develop a joint Hawai'i-Alaska website to make existing modeling results more accessible for resource managers who need to incorporate climate change projections into their planning and outreach efforts. The project will also co-produce new standardized hydro-meteorological products that will help address the uncertain future of precipitation extremes.

Impacts of Increased Light Transmittance on Ocean Heating, Primary Productivity, and Carbon Cycling Across a Pacific Arctic Continental Shelf Gradient

Principal Investigator: Karen Frey

Funding Agency: National Science Foundation

Seasonal sea ice in the Pacific Arctic Region (PAR) has declined significantly, with large portions of this region becoming ice-free by mid-summer. This Pacific Arctic sector is also among the most biologically productive marine ecosystems in the world and acts as an important sink and perhaps seasonal source of carbon. Although sea ice is a dominant feature in these shelf environments at high-latitudes, we are only beginning to understand how changes in sea ice (through its influence on light, seawater temperature, salinity, and nutrient availability) will specifically affect ecosystems in these regions. This project adds new optical measurements of light transmittance through the upper ocean water column

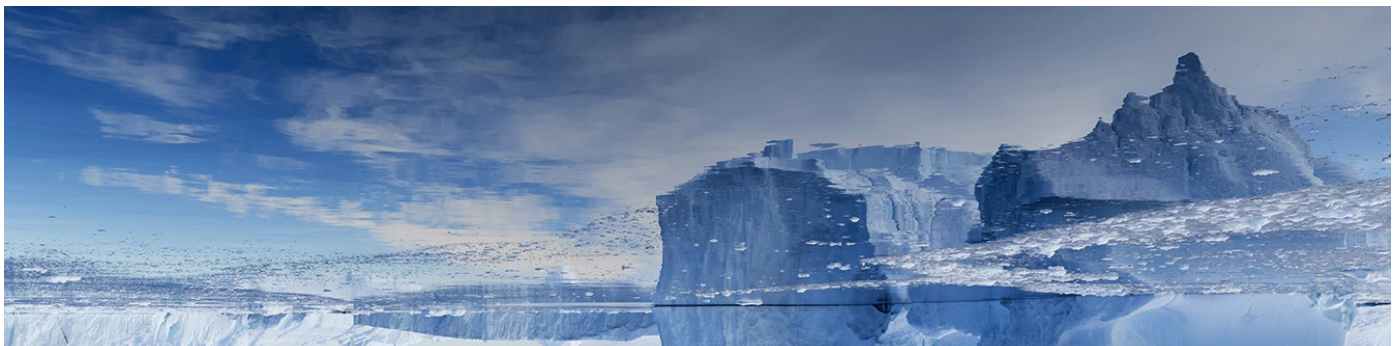
across a continental shelf gradient to an existing suite of observations on the Synoptic Arctic Survey cruise to the central Arctic Ocean. The research will: (1) test the hypothesis that light transmittance increases with declines in sea ice cover and varies with light absorbing impurities in the water column, and (2) utilize the optical measurements to elucidate questions surrounding vertical heat distribution in the water column, primary productivity, and the photodegradation of dissolved organic matter.

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

Principal Investigator: Karen Frey

Funding Agency: National Science Foundation

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



is the impact of seasonal changes in hydrography on the lateral and vertical distribution of primary production and export production to the benthos? (3) What will be the ecosystem responses to latitudinal changes in environmental drivers and can we forecast the biological response to components of the food web through ecological modeling?

Remote Sensing of River Carbon Fluxes to the Ocean

Principal Investigator: Karen Frey
Funding Agency: National Aeronautics and Space Administration

Working collaboratively with researchers at Northeastern University, this project will develop remote sensing data and LOADEST (Load Estimator software) modeling of dissolved organic carbon for rivers globally and across the Arctic.

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

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

Over the last 30 years, surface seawater temperatures in the Gulf of Maine have risen at three times the global average, rates of sea-level rise have accelerated, and precipitation has increased. Coupled with these changes in climate and sea level are substantial changes within rapidly urbanizing watersheds that influence water, sediment, and nutrient delivery to marshes and estuaries. The Plum Island Ecosystems (PIE) Long Term Ecological Research (LTER) site is developing a predictive understanding of the response of a linked 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 addresses three critical questions: (1) How will the geomorphic configuration of the marsh and estuary be altered by changes in the watershed, sea-level, climate, and feedbacks internal to the coastal system? (2) How will changing climate, watershed inputs, and marsh geomorphology interact to alter marsh and estuarine primary production, organic matter storage, and nutrient cycling? (3) How will key consumer dynamics and estuarine food webs be reshaped by changing environmental drivers, 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.

Applied Science to Catalyze Natural Climate Solutions

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

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

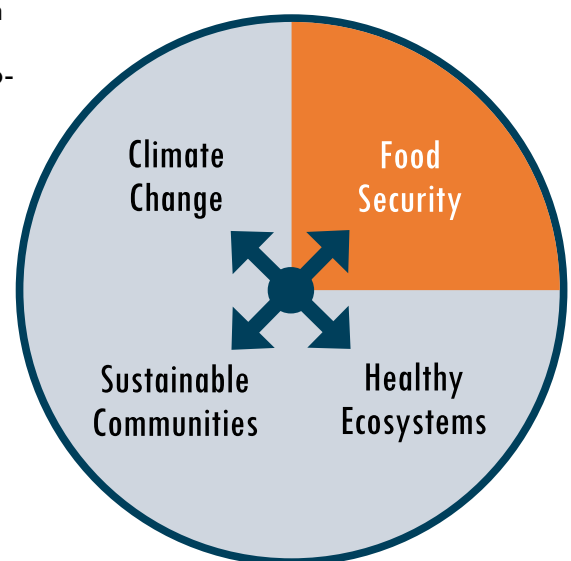
Avoided Deforestation as a Climate Opportunity in the U.S.

Principal Investigator: Christopher Williams
Funding Agency: The Nature Conservancy

Forests are a globally-significant store of carbon, but this store is vulnerable to release from disturbance processes such as harvesting or fires that contribute to global warming. At the same time, intact forests serve as a major offset to rising CO₂ concentrations as forest growth becomes stimulated by rising CO₂ levels, enabling forests to absorb about one third of annual carbon emissions from fossil fuels and land use change. The balance of these processes is constantly changing and it varies widely from region to region. Expanding upon previous work in the New England states, this project will provide the data, scientific analyses, and communications needed for quantifying the full climate impacts (e.g., carbon emissions and forgone carbon sequestration) of potential forest loss in the conterminous U.S. This project will also extend the work to include the albedo-induced radiative forcing and associated CO₂ equivalent emissions that would be caused by avoiding forest conversion.

LOCAL AND GLOBAL FOOD SECURITY

Population growth, shifting consumption, regional conflicts, degradation of ecosystem services, natural hazards, and a changing climate are among the factors that threaten food security across the globe. Marsh Institute researchers are at the forefront of efforts to help ensure food security worldwide. These threats are particularly severe in the developing world. For example, **Lyndon Estes'** interdisciplinary and multi-institutional collaborative work investigates the drivers and impacts of agricultural change, with a particular focus on sub-Saharan Africa. His recent work includes the use of satellite imagery and ground-truthing to accurately map the location of cropland and particular crops in order to facilitate agricultural extension services, the characterization of agricultural production and associated land use change under different urbanization scenarios, and the development of sensor networks to understand changing rainfall patterns and relationships to farmers' planting and harvesting decisions. Different challenges can confront sustainable food production in developed countries. For example, **Robert Johnston** is investigating how the public perceives northeast U.S. shellfish aquaculture, and how new operations can be developed in ways that maximize public support. Other threats to food security result from the agricultural use of pesticides and other chemicals, with acute and chronic effects on agro-ecosystem services. For example, **Dana Bauer** is working with multi-disciplinary teams to evaluate the biophysical and socio-economic conflicts and tradeoffs among pest management and pollination services in U.S. agriculture. Through these and other projects, Marsh Institute researchers are helping to ensure the resilience of agricultural systems upon which societies depend.



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

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

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

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 honeybees 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 project is to develop holistic pest-pollinator joint management regimes that are effective, profitable, and sustainable. The project will: identify insecticide management strategies that simultaneously optimize pest suppression while minimizing non-target exposure to pollinators; determine the consequences of neonic exposure for honeybee and wild bee health; and assess the ecological and socioeconomic trade-offs among pollinators, pests, crop yield, and farm profitability resulting from alternative pest management regimes. This interdisciplinary research partnership involves collaborators from Purdue University, Michigan State University, Ohio State University, and the University of New Hampshire. Marsh Institute researchers are leading the economic analysis of grower decision making.



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

Principal Investigator: Lyndon Estes

Funding Agency: Gates Foundation and Farmerline

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

Linkages and Interactions between Urban Food Security and Rural Agricultural Systems

Principal Investigator: Lyndon Estes

Funding Agency: National Science Foundation

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

of California Santa Barbara, and University of Illinois at Urbana-Champaign. Marsh Institute researchers are responsible for characterizing rural agricultural production using remote sensing, and modeling the land use impact of different urbanization scenarios.

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.

Enabling Crop Analytics at Scale: AGData Acceleration Facility

Principal Investigator: Lyndon Estes

Funding Agency: Farmerline and TetraTech

Smallholders in Africa often lack access to the inputs and information that can help boost their productivity and resilience to climate change. One key reason for this is the absence of data that accurately map where croplands are and what crops are grown on them. Making such maps is challenging because it requires the ability to use satellite imagery to accurately map the boundaries of smallholders' fields over large areas. This project will provide the cropland and crop type mapping capabilities that will allow provisioning of new agricultural extension services to farmers in Ghana, and demonstrate the ability to extend such services to Tanzania.

A Region-Wide, Multi-Year Set of Crop Field Boundary Labels for Sub-Saharan Africa

Principal Investigator: Lyndon Estes

Funding Agency: Lacuna Fund

This project builds upon previous work, using satellite imagery to accurately map the boundaries of smallholders' fields over large areas and accurately label these crop fields covering two mapping regions in Western/Central Africa and Eastern/Southern Africa. It will develop and prepare the labelling platform for use, and provide technical support and guidance to project partners on how to use the platform.

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

Principal Investigator: Robert J. Johnston

Funding Agency: NOAA, National Sea Grant

The largest sector of the U.S. marine aquaculture industry is molluscan shellfish (e.g., oysters, clams and mussels), which accounts for more than 50% of total production. A large number of shellfish operations are concentrated within Connecticut, Rhode Island and Massachusetts,

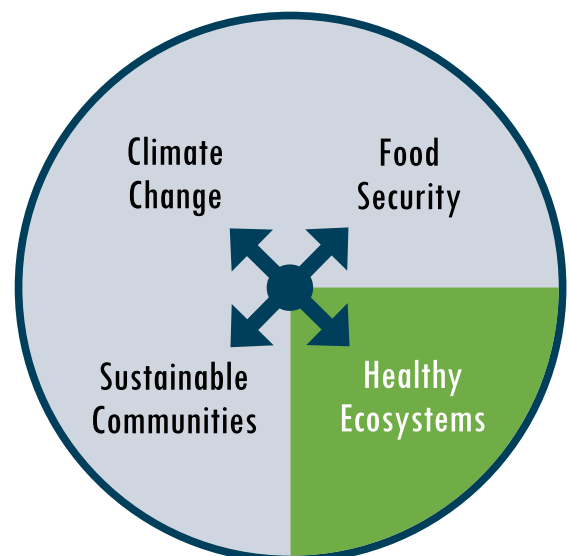
where significant growth potential exists and in which stakeholder-based efforts are being implemented to support and expand this important U.S. food production sector. One of the challenges facing future growth of the shellfish aquaculture industry in this region is siting aquaculture operations in the face of negative public perceptions and concerns highlighted by the media about environmental impacts and human use conflicts. Although in some cases these perceptions may be grounded in personal experience or accurate information, in other cases they may be motivated by a misunderstanding of the science or a past inability of aquaculture stakeholders to speak to the concerns relevant to the public. This project examines public values and support for prospective shellfish aquaculture expansion programs that could be enacted region- or state-wide, as determined by alternative development strategies. The analysis also considers the systematic effect of different types of information on this support, and how values and perceptions differ across resident groups. The goal 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.



A panel of geography professors (left to right: Karen Frey, Lyndon Estes, John Rogan, Deb Martin, and Gil Pontius) participated in Clark's Presidential Inauguration Academic Symposium in April. The session "Geography of Changing Land and Seas" showcased how the panelists and their students are working towards understanding and solving some of the world's greatest challenges from social justice to food security to climate change.

HEALTHY AND VIABLE ECOSYSTEMS

Healthy and productive ecosystems, and the plethora of services they provide, are crucial for sustaining human well-being. Ecosystem services include provisioning of food, water, and energy, purification of air and water, and protection from natural hazards, among many others. However, many ecosystems across the globe are being threatened by a changing climate, together with anthropogenic activities such as overuse of natural resources, conversion of natural land covers to impervious surfaces, and inadequate waste disposal. Marsh Institute researchers are at the forefront of science and policy efforts to manage and protect ecosystems and the ecosystem services they provide. For example, **Dana Bauer** and colleagues are integrating social and ecological models to assess financial incentives for voluntary water conservation as a strategy for reducing conflict in water-scarce regions. **Lyndon Estes** is using optical imagery to characterize changing forested landscapes in order to facilitate land tenure management and the design of conservation policies. **Robert Johnston** is working with an international team to understand the damages caused by marine plastic pollution and identify the benefits from international coordination and cooperation. Johnston is also investigating solutions to the widespread problem of nitrogen runoff from residential lawns in urban and suburban landscapes. **Robert (Gil) Pontius** is collaborating on a large-scale effort to develop detailed land cover change maps of Brazil that will support sustainable management. **Florencia Sangermano** is evaluating the effects of habitat loss on small mammals functional diversity and the associated risk of disease spillover to humans. Through these and other projects, Marsh Institute researchers are helping to maintain healthy ecosystems and conserve the supply of critical ecosystem services.



Conservation Incentives and the Socio-Spatial Dynamics of Water Sustainability

Principal Investigators: Dana Marie Bauer and Robert J. Johnston
Funding Agency: National Science Foundation

Disputes over scarce water resources are common worldwide and there is a growing interest in voluntary incentives (e.g., payments offered to water users) as a strategy for reducing conflicts. Incentive-based programs hold promise, but uncertainties remain regarding how state and non-state environmental organizations may implement them. Efficient and effective implementation requires strategic allocation of financial incentives across space and time. Collaborating with colleagues from multiple institutions (University of Oklahoma, Florida International University, George Mason University, Oklahoma State University, and Texas A&M), this project investigates how interactions among social, hydrological, and biological spatial dynamics affect the sustainability of human-freshwater systems operating under incentive-based conservation. Integrated socio-ecological modeling will be used to investigate sustainability dilemmas typical of water-limited river basins worldwide, leading to a set of key insights for understanding and managing these systems. The focus of this project is on water systems in areas with extensive agricultural use, but the findings have the potential to transform understanding of the ways in which conservation incentives might enhance the sustainability of a wide range of integrated human-natural systems.

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

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

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

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

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

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

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

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

There is significant concern about the environmental impact of residential lawns, especially the extent to which they export nutrients and how this export is related to human behavior such as lawn fertilizer use. Despite past research seeking to characterize residential lawn care, there is no clear understanding of the most effective means to influence lawn care practices across the Long Island Sound watershed. Past research has focused on general attitudes and socio-economic factors associated with residential land management, including behaviors such as fertilizing, irrigating and mowing. However, this literature has been unable to inform plans that are effective at influencing lawn care practices, because it has not produced a satisfactory explanation for the variation in practices that influence nitrogen export and stormwater runoff, or evaluated the extent to which

specific programs or policies can influence these practices moving forward. Hence, lawn care and its impacts remain an unresolved challenge emphasized by Long Island Sound strategic planning. This interdisciplinary research project, with collaborators from City University of New York and Florida Atlantic University, will adapt and extend existing integrated models, experimental designs, and survey instruments to model the dynamics of lawn care behaviors across the Long Island Sound watershed.

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

Principal Investigator: Robert J. Johnston

Funding Agency: U.S. Environmental Protection Agency

Stated Preference (SP) methods are survey-based approaches to calculate the economic value of environmental improvements, and provide the only means to measure total use and nonuse willingness to pay (WTP) for water quality change. Yet water quality has multiple characteristics that pose challenges for WTP estimation: water quality can vary spatially and temporally; the role of small streams is often under-appreciated; and water quality benefits are often realized through direct and indirect effects on other ecosystem services valued by different user and nonuser groups. This large, interdisciplinary project will develop and evaluate a next-generation approach to SP valuation that will restructure the way that WTP is elicited and estimated. The approach is designed to estimate use and nonuse WTP for linked water quality and ecosystem service improvements across river networks. The project, which involves collaborators

from the University of New Hampshire, Virginia Technological Institute, and ICF, advances the methods used by government agencies and others to calculate the benefit of water quality improvements to society.

Next Generation Choice Experiment Architecture for Spatially-Explicit Agricultural Conservation and Ecosystem Service Valuation

Principal Investigator: Robert J. Johnston

Funding Agency: U.S. Department of Agriculture

The USDA spends more than \$5 billion annually on conservation programs to enhance environmental quality, ecosystem services and agricultural sustainability. Yet credible information on economic (and particularly non-market) benefits is often lacking, particularly for heterogeneous conservation practices that occur over large spatial scales. Current economic valuation methods are challenged by the individualized and spatially heterogeneous ways that people understand, use, and value ecosystem services over different spatial scales, posing questions for the validity and credibility of benefit estimation. This project will develop and evaluate next-generation tools designed to meet these challenges. To develop these methods, the project team will leverage advances in online, interactive map-based survey architecture, together with novel approaches for stated-preference survey design, Bayesian econometrics, and integrated assessment modeling. The approach will be demonstrated using a case study of conservation and aquatic ecosystem service improvements over the state of Virginia, but will be generalizable to other applications.



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

Principal Investigator: Robert J. Johnston

Funding Agency: Australian Research Council

Environmental programs and policies cost billions of dollars per year. Environmental policy makers and managers can be assisted in their decisions 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, amenity values of urban wetlands, 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: (1) by demonstrating quantitative analyses to support a range of decisions about NMV methods; (2) by developing heuristics about when particular methodological choices are more likely to be preferred; and (3) by assisting decision makers to think through these decisions in a more sophisticated and complete way.

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

Principal Investigator: Robert J. Johnston

Funding Agency: U.S. Department of Agriculture

The USDA spends over \$5 billion annually on conservation programs to enhance ecosystem services that promote agricultural sustainability, often targeting benefits such as water quality and aquatic ecosystem services. While the biophysical impacts of these programs can be estimated using established models, the economic benefits are generally unknown. Addressing this shortcoming requires practical, reliable and cost-effective benefit transfer methods explicitly designed for large-scale ecosystem service valuations. Meta-regression models are increasingly used in benefit transfers, and these models can be specified to link directly to biophysical models that predict policy outcomes. Despite this promise, further methodological advances are required if meta-regression models are to be used widely for large-scale ecosystem

service valuations. This project will develop and evaluate an integrated biophysical and meta-analytic benefit transfer model designed to estimate spatially explicit ecosystem service benefits from large-scale agricultural conservation policies, while addressing limitations of prior benefit transfer approaches. The new approach, based on Bayesian locally weighted meta-regression modeling, will be demonstrated using case studies of conservation programs that enhance aquatic ecosystems.

Methods and Software to Understand and Build the MapBiomass Data

Principal Investigator: Robert Gilmore Pontius Jr.

Funding Agency: Instituto Humanize

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

Land Use Change, Ecosystem Resilience, and Zoonotic Spillover Risk

Principal Investigator: Florencia Sangermano

Funding Agency: National Science Foundation

Biodiversity loss is one of the most severe global environmental problems caused by habitat loss, leading to functional diversity changes and profound cascading effects on the abundance, composition, and ecology of fauna and flora. These changes affect species interactions and ecological function and services, with impacts that can reach human health and well-being, primarily through changes in disease regulation services. The Brazilian Atlantic Forest is a hotspot for biodiversity and rodent diversity, with most rodent species considered pathogen reservoirs or hyper reservoir species, making the area a hub for future emerging infectious diseases. This project: (1) evaluates the effects of habitat loss on small mammals' functional diversity (i.e., community composition and interaction network structure), and assesses their effect on pathogen spillover risk throughout the Brazilian Atlantic Forest; and (2) evaluates the effects of forest restoration on the recovery of this functional diversity and reduction of spillover risk.

SUSTAINABLE COMMUNITIES AND LIVELIHOODS

Public and private institutions and governance determine whether and how people are able to achieve sustainable levels of consumption and the resilience of populations to social upheavals and environmental change. Marsh Institute researchers seek to promote improved human condition across the globe, with particular emphasis on challenges related to disadvantaged populations, and social and environmental justice. Much of this work coordinates closely with community partners to promote positive social change. For example, **Halina Brown** and **Philip Vergragt** continue their founding work with the Sustainable Consumption Research and Action Initiative, a network of practitioners focused on facilitating the transition to a more sustainable society by focusing on patterns of consumption. **Edward Carr** and **Anita Fabos** are working with the Belmont Forum to address human rights concerns related to the dynamics of involuntary migrations. **Stefanie Covino** is working with the Blackstone Watershed Collaborative to facilitate the adoption of green infrastructure and other nature-based water quality strategies by stakeholder communities within the watershed. **Margaret Post** is evaluating a program that promotes racial and maternal birth equity in low-income communities. **John Rogan** and **Deborah Martin** are working with the Massachusetts Executive Office of Energy and Environmental Affairs and the Opacum Land Trust to assess the impact of tree planting on residential heating and cooling and respiratory illnesses in low-income urban communities. **Laurie Ross** and **Jennifer Safford-Farquharson** are working with The Community Builders to improve the quality, timeliness, and holistic care of crisis intervention and mental health services.



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. Brown and Vergragt are co-organizers of the fifth International SCORAI Conference, *Transforming Consumption-Production Systems Toward Just and Sustainable Futures*, co-convened with the European Roundtable on Sustainable Consumption and Production (ERSCP) and the University of Wageningen. Brown and Vergragt are also active in implementation of the Newton (MA) Climate Action Plan that Halina spearheaded.

Migration, Transformation and Sustainability

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

Unprecedented concern exists regarding involuntary migration affecting insecurity and human rights around the globe. However, both domestic and international migration has enormous transformative potential for individuals and societies. Existing theories of transformation fail to recognize both positive and

negative impacts of the movement of people. This gap limits explanations and intervention strategies for sustainability. The objective of this research is to expand knowledge of transformations to sustainability by incorporating specific migration dynamics including: the impact of aggregate flows of people on sustainability; the individual life course dimensions of sustainability; and the governance of migration and sustainability. This project will develop a comprehensive 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.

Advancing Green Infrastructure in the Blackstone Watershed: Identifying Municipal Priorities, Workshopping Solutions, and Mapping Implementation

Principal Investigator: Stefanie Covino
Funding Agency: U.S. Environmental Protection Agency and Narragansett Bay Estuary Program

Nature-based solutions and green infrastructure, such as the planting of trees for cooling and the use of roadside vegetation to mitigate pollutant runoff, are nothing new. However, many Blackstone Watershed communities are still not including nature-based solutions as a priority for new developments at the scale or frequency of what is possible. This project seeks to build long-term relationships with community stakeholders to identify local goals that can be addressed through nature-based solutions and remove barriers to implementation. The Blackstone Watershed Collaborative will provide technical assistance and identify potential funding sources. The project will initially focus on two communities with significant environmental justice populations: Worcester, MA and Woonsocket, RI.



Incorporating Underserved Voices to Improve Capacity and Structure in the Blackstone Watershed Collaborative

Principal Investigator: Stefanie Covino
Funding Agency: Center for Large Landscape Conservation

With its headwaters located in Worcester, Massachusetts, the Blackstone River has a reputation as a heavily developed, urbanized river. The watershed includes 29 municipalities in Massachusetts and 10 municipalities in Rhode Island. The most heavily urbanized areas are located in Worcester, MA; Woonsocket, RI; Central Falls, RI; and Pawtucket, RI, all of which are home to mapped environmental justice populations. The Blackstone Watershed is also the ancestral homeland of the Nipmuc Nation, recognized by the Commonwealth of Massachusetts as a sovereign people. The Blackstone Watershed Collaborative exists to improve the health and resilience of the Blackstone Watershed communities and help meet the increasing challenges to water quality and climate change impacts. This project will improve organizational capacity and allow the collaborative to deeply engage with under-represented populations in the watershed, including Indigenous communities such as the Nipmuc Nation. Specifically, this project will inform establishment of an inclusive governance structure, creation of a 5-year fundraising plan, and establishment of a list of priority projects.

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

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

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

Community Change Evaluation Projects

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

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

Studying How 501(c)(3)-(c)(4) Hybrid Organizations Build Community Leadership and Strengthen Democratic Processes that Improve Community Well-Being

Principal Investigator: Margaret Post
Funding Agency: Robert Wood Johnson Foundation

This project will investigate how 501(c)(3)-(c)(4) hybrid organizations mobilize grassroots participation, impact policy, and influence economic and governing power through the engagement of communities that have experienced chronic disinvestment, economic inequality, and isolation. Results will inform efforts to build community leadership and create pathways for constituencies to engage in democratic processes that improve community well-being.

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

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

The Massachusetts communities of Ware and Southbridge have significantly above average incidence of respiratory conditions among their populations and low existing tree canopy cover. In a unique partnership among cities, community health care facilities, grassroots neighborhood centers, and regional land trusts, this project will focus on the ability of cost-effective and spatially-strategic community tree planting to cool low income neighborhoods, shade walking routes, and filter pollution near schools. In so doing, it meets several high priorities for Massachusetts' Forest Action Plan. 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.



Revitalizing the Hadwen Arboretum, Columbus Park Neighborhood

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

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

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, and other community organizations, 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.

Boston Children's Collaboration for Community Health

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

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

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

CENTERS AND PROGRAMS

BLACKSTONE WATERSHED COLLABORATIVE

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

been vital to the ecological, social, and economic health of the region for centuries. Along with the Taunton River, the Blackstone provides freshwater to the Narragansett Bay downstream and supports ecological health through large intact forests and cold-water fisheries as well as thriving commercial and recreational benefits such as fishing, kayaking, and biking. Local river advocates have devoted tireless efforts to address the watershed's industrial past, ongoing urbanization, and climate change impacts. Despite this progress, work is still required to assure a healthier and more resilient watershed over the coming years.



Katie Liming (MS ES&P '22) and Stefanie Covino (MS ES&P '15) participating in the Blackstone Commons Expedition, an event focused on drawing attention to the ongoing challenges facing the watershed.

The Blackstone Watershed Collaborative was established in 2021 to convene stakeholders throughout the bi-state watershed and offer technical assistance, outreach, educational materials, and networking to advance the priority goals of the *Blackstone River Watershed Needs Assessment Report*.

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

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



HUMANITARIAN RESPONSE AND DEVELOPMENT LAB

The Humanitarian Response and Development Lab (HURDL) is a development and humanitarian assistance research and implementation lab. Led by **Ed Carr** (below right), 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 U.S. Agency for International Development, the World Bank, the Red Cross Climate Center, and the Climate Services Partnership, among others, creating a broad network of experience and expertise to inform its work. More information can be found on the lab's website (www.hurdl.org).



CENTER FOR THE STUDY OF NATURAL RESOURCE EXTRACTION AND SOCIETY

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

infrastructure investment, energy, and agroindustry. Center research—led by Professors **Denise Humphreys Bebbington** (IDCE), **Anthony Bebbington** (Geography) and **John Rogan** (Geography)—involves policy and practical engagements with philanthropic, non-governmental, and public sector bodies. For example, research into the effects of extractive industry and large-scale infrastructure on forest cover and human rights in the Amazon, Central America, Mexico and Indonesia involved Clark researchers in direct discussions with the Climate and Land Use Alliance regarding the implications of their findings for the Alliance's work. Researchers at the Center have also worked closely with Oxfam on elements of its Extractive Industries program, advising on overall global and Latin American strategy, and conducting research designed to feed into program and policy design in Honduras, Peru and East Africa in particular. This past year, the center hosted a seminar series and a brown-bag lunch forum covering various extractives related issues. More information can be found on their website (www.extractivesatclark.org).

JEANNE X. KASPERSON RESEARCH LIBRARY

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

under the aegis of the Marsh Institute, the Graduate School of Geography, and the Department of International Development, Community, and Environment (IDCE). The library is committed to serving the educational functions of Clark University and the broader community in order to further research related to socio-environmental sustainability. An integral part of the Marsh Institute, the Kasperson Library offers one of the most extensive collections in North America on environmental risk and hazards, environment and development, and the human dimensions of global environmental change. The library also has significant holdings on the subjects of sustainable development, environmental technology, water resources, and energy policy, as well as other unique special collections such as its extensive holdings on radioactive waste management. Most recently, the library became home to the Worcester Refugee Archive, a collection of local and global resources on the topic of refugee resettlement in Worcester County. In addition to journal articles, the archive contains theses, government reports, and newspaper articles dating back to the 1970s. The library has attained national and international recognition as a premier collection of research materials, and particularly of fugitive materials and unpublished literature in its areas of specialization. It provides information and research support for university researchers; undergraduate and graduate students; visiting scholars; regional experts; federal, state, and local agencies; industry; schools; and consulting firms. The library holds has more than thirty-five thousand volumes related to it's focus areas, and computer and internet resources. Library Director **BJ Perkins** (insert) and other library staff provide personalized research assistance.



The Marsh Institute provides innovative, applied research opportunities for Clark graduate and undergraduate students. Programs range from endowed awards for student-initiated research to large-scale research projects promoting student involvement and hands-on learning, often in interdisciplinary and multi-institutional settings. Among these programs, the annual **Albert, Norma and Howard Geller '77 Endowed Research Awards** support student-initiated research projects that advance our understanding of natural resource and environmental sustainability and develop practical improvements that move society toward more sustainable outcomes. Each year, the **Human-Environment Regional Observatory (HERO) program** provides funding for a cohort of select undergraduate students to engage in research on human-environment relationships in New England. For eight weeks during the summer, HERO Fellows conduct hands-on research under the mentorship of Clark University faculty and graduate students. **Faculty-led research projects** involving students cover a range of topics including: investigating climate change impacts on marine ecosystems in the Pacific Arctic region, developing a scalable and cost-effective agricultural land-cover mapping program in sub-Saharan Africa, surveying farmers across the U.S. about their conservation practices, modeling water supply and wastewater-sanitation systems for the Mexico City Basin, surveying homeowners in Long Island Sound regarding their lawn care practices, and identifying and predicting changes in coastal vegetation in the Plum Island (Massachusetts) Ecosystem. Students are engaged in all aspects of the research from data collection and analysis through presentation and publication of results. Throughout 2022, Marsh Institute grants and endowments supported eight undergraduate students, thirty-six graduate students, and one post-doctoral fellow.



**STUDENT
RESEARCH**

HUMAN-ENVIRONMENT REGIONAL OBSERVATORY

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

John Rogan, HERO Fellows analyze the causes and consequences of global environmental changes at local scales. Among its many benefits, the HERO program provides students with opportunities to conduct, present, and publish research alongside faculty colleagues. HERO research has been funded by multiple awards from various foundations and government agencies, most recently the John T. O'Connor '78 Endowed Fund for Environmental Studies, the U.S. Department of Agriculture, and the National Fish and Wildlife Foundation.



2022 HERO Fellows (left to right): Nicole Buckley, Charlotte Zieselman, Lucy Fleming, Danielle Hall, Nicholas Geron (graduate mentor), Shradha Birdika, Apple Gould-Schultz (graduate mentor), and Madeline Regenye (graduate mentor)

During the summer of 2022, the HERO Team worked with Groundwork Rhode Island, a community-based organization working to build healthier, more resilient, and more equitable urban communities by improving the physical environment and creating economic opportunities for residents. HERO fellows surveyed tree health and local temperature and air quality conditions in environmental justice neighborhoods in Providence, Central Falls and Cumberland (RI). Interviews with residents revealed positive perceptions of tree benefits for air quality and aesthetics, as well as support for more tree planting. The HERO team presented their research at the New England-St. Lawrence Valley Geographical Society's annual conference held at Salem State University in October 2022 and took home the Best Poster award!

This past year, the HERO team also partnered with Professor **Rinku Roy Chowdhury** on a collaborative project based in and around the Broad Meadow Brook Wildlife Sanctuary (Worcester, MA). The team conducted in-person interviews with neighborhood residents to better understand their use and perceptions of the sanctuary.

GELLER ENDOWED STUDENT RESEARCH AWARDS

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

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



William Cruice
PhD Geography
Faculty Mentor:
James McCarthy

The Globalization of Offshore Wind Energy: Green Skills, Workers Competition, and Transnational Organization

Recent approval for the construction of the United States' first large-scale offshore wind project offers strong indications that the U.S. will become a major investment location for the increasingly global offshore wind industry. It remains to be seen, however, whether the anticipated growth of offshore wind in the U.S. will translate into an employment boom of equal magnitude and what such growth might mean in terms of a 'just transition' for workers in the U.S. energy industry. This research examines the uneven development of the wind energy industry across North America and Western Europe. More specifically, it focuses on the fragmentation of the offshore wind labor process between intellectual and manual labor and the geographical expression of this fragmentation, in order to understand the skills needed to advance the renewable energy transition. The research also focuses on the efforts of workers to avoid competing with one another at the expense of working conditions and environmental outcomes. Funds from the Geller Award will be used to conduct in-depth interviews with representatives of firms, industry associations, educational institutions, research organizations, and trade unions, all key actors in the wind energy global production network.



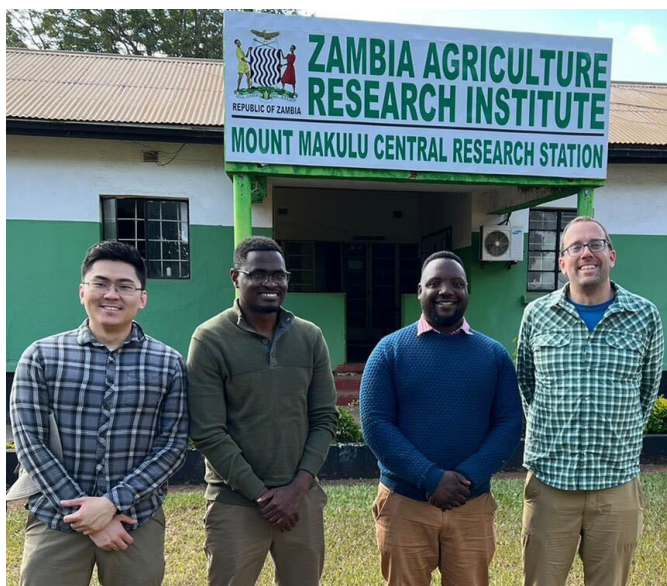
Christina Martin
BA/MS Biology
Faculty Mentor:
David Hibbett

Can Mushrooms Help Save the Bees?

Bees are essential for creating sustainable and biologically diverse ecosystems. They ensure the survival and reproduction of the majority of Angiosperm plants, making them critical species that the majority of organisms in an ecosystem depend upon. Bees also contribute greatly to the sustainability of the human food system, since 35% of global food production is reliant on the pollination of crops, which is largely conducted by migratory honey bee hives. Beekeepers have been experiencing increasing declines in their bee populations as environmental conditions have reduced bees' ability to cope with hive pathogens. Finding a solution to improve bees' immunity is fundamental to restoring global ecosystems and food systems, so it has become increasingly important to find sustainable treatments for bee pathogens. Recent research has begun exploring the medicinal properties of fungi to help reduce viral levels in bees. This research will contribute to the ongoing efforts to develop effective treatments for bee pathogens by investigating the effects of oak extractives and the fungal extracts of *Fomes fomentarius* and *Ganoderma applanatum* grown on oak wood on the reduction of Deformed Wing Virus levels in honey bees. Funds from the Geller Award will be used for quantitative PCR (qPCR) reagents and other routine laboratory supplies.

POLLINATOR-DEPENDENT CROP SYSTEMS

Marsh Institute Assistant Director **Dana Bauer** and recent graduate **Lillian Sartorius** (BA Economics and International Development) are developing an online survey of farmers across the conterminous U.S. who grow fruit and vegetable crops reliant on animal (mostly bee) pollination. The research is focused on understanding farmer's perceptions of and willingness to participate in conservation programs that support pollinator health.



SUB-SAHARAN AFRICA AGROECOSYSTEM

Clark Geography graduate students **Sitian Xiong** (left) and **Michael Cecil** (right), with University of Illinois student Protensia Handunka (second from left) and Allan Chilenga (second from right), agronomist at the Zambia Agriculture Research Institute. Under the mentorship of Professor **Lyndon Estes**, the Clark students are using a combination of household interviews, government data, field trials, and ground and satellite sensors to study smallholder agriculture.

THE PACIFIC ARCTIC MARINE ECOSYSTEM

Graduate student **Clare Gaffey** (PhD Geography) is working on board the US Coast Guard Cutter Healy as part of the NSF Synoptic Arctic Survey (SAS) science mission. Under the mentorship of Professor **Karen Frey**, Clare is sampling SAS stations across a continental shelf gradient from the Chukchi Sea into the deep Arctic Ocean basin to investigate how Arctic marine ecosystems and carbon cycles are transforming with climate change.



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



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AOYAMA**
Geography



**DANA
BAUER**
Marsh Institute



**ANTHONY
BEBBINGTON**
Geography



**ASHA
BEST**
Geography



**HALINA
BROWN**
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Management



**JUNFU
ZHANG**
Economics

MARSH INSTITUTE STEERING COMMITTEE

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

Anthony Bebbington

Professor, Graduate School of Geography

Edward Carr

Professor and Director, International Development, Community, and Environment

Timothy Downs

Associate Professor, International Development, Community, and Environment

Lyndon Estes

Associate Professor, Graduate School of Geography

Karen Frey

Professor, Graduate School of Geography

Robert Goble

Research Professor, George Perkins Marsh Institute

Deborah Martin

Professor, Graduate School of Geography

Laurie Ross

Professor, International Development, Community, and Environment

Rinku Roy Chowdhury

Professor, Graduate School of Geography

Christopher Williams

Professor, Graduate School of Geography

EX-OFFICIO MEMBERS

Yuko Aoyama

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

Dana Marie Bauer

Assistant Director, George Perkins Marsh Institute

Robert J. Johnston

Director, George Perkins Marsh Institute

NEW FACES AT THE MARSH INSTITUTE



Jon Denton-Schneider

Jon Denton-Schneider studies development economics and economic history with an emphasis on human capital — especially health — in sub-Saharan Africa and Latin America. His research focuses on the historical causes and economic consequences of poor health in these regions, as well as the policies that can remedy its negative impacts. Denton-Schneider received a Fulbright grant to study the post-NAFTA business environment in Mexico. He holds a master's in Latin American studies from the University of Arizona and earned his doctorate in economics from the University of Michigan, where he was a Weiser Emerging Democracies Fellow and a predoctoral trainee in economic demography in the Population Studies Center.



Gustavo Oliveira

Gustavo Oliveira is a human-environment geographer whose research focuses on the global political ecology of agribusiness and agroecology, particularly on land struggles and the transnational soybean sector. A member of the United Nations Sustainable Development Solutions Network's Science Panel for the Amazon, his current book project is "Brazil, China, and the Global Land Grab." Oliveira is also co-principal investigator of a USDA-funded project on the COVID-19 pandemic's impact on U.S. food supply chains in California, Florida, and the Midwest. He holds a doctorate in geography from the University of California Berkeley and a master's in philosophy from the University of Colorado Boulder.

MARSH INSTITUTE SEMINAR SERIES

Each year, the Marsh Institute sponsors formal lectures and seminars that expose faculty and students to contemporary research on human-environment interactions, foster rich discussions, and catalyze future research. These seminars include the George Perkins Marsh Institute/Jeanne X. Kasperson Library Seminar Series, the Albert, Norma, and Howard '77 Geller Endowed Lecture Series, and the Debra I. and Jeffrey A. Geller Endowed Lecture Series.



"Towards a Critical Geospatial
Analysis of Police Violence"

ASHA BEST

Assistant Professor of Geography
Clark University



"Regenerative Urban Ecology: A Next
Phase for Science and Society"

MORGAN GROVE

Team Leader
USDA Forest Service



"The Future of the Blackstone
Watershed"

STEFANIE COVINO

Blackstone Watershed Program
Manager, Clark University



"Hurry Up but Wait: Gigawatt-Scale
Deployments of Offshore Wind
Power and Cross-Cultural Stakeholder
Engagements"

BONNIE RAM

Associate Director for Strategic
Initiatives, Center for Research
in Wind Energy



"Challenges and Opportunities in
Urban Greening Theory and Practice"

THEO EISENMAN

Associate Professor of Landscape
Architecture and Regional Planning,
UMass Amherst



"Connecting Massachusetts'
Landscapes to Soundscapes"

FLORENCIA SANGERMANO

Assistant Professor of Geography
Clark University



"Climate Variability and Drought
in Pacific Islands"

ABBY FRAZIER

Assistant Professor of Geography
Clark University

PANELS, EDITORSHIPS AND OTHER AWARDS

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

ADVISORY BOARDS AND COMMITTEES

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

Halina Brown is chairperson of Newton (Massachusetts) Citizens Commission on Energy and **Philip Vergragt** co-chairs the Newton Task Force on Electric Vehicles, both part of the Newton Climate Action Plan.

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

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

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

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

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

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

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

Robert Johnston serves on the Advisory Group for the International Whaling Commission, providing guidance on the socio-economic values of cetaceans' contributions to ecosystem functioning.

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

Robert (Gil) Pontius serves on the Scientific Advisory Committee of MapBiomass.

Rinku Roy Chowdhury is a lead author of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' Global Assessment Report.

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

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

EDITORSHIPS AND PROFESSIONAL SERVICE

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

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

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

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

AWARDS AND RECOGNITIONS

Robert (Gil) Pontius was selected as a 2022-2023 Fulbright Scholar to share his expertise in analyzing digital maps with scientists, professors, and students in Porto Alegre in Southern Brazil.

Florencia Sangermano was selected as a 2022 Kavli Fellow by the U.S. National Academy of Sciences, an elite group of the nation's brightest young researchers from industry, academia, and government who have already made recognized contributions to science.

RECENT BOOKS AND OTHER PUBLICATIONS

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

Dana Bauer and colleagues published the article “Socioecological factors and farmer perceptions impacting pesticide use and pollinator conservation on cucurbit farms” in the journal *Frontiers in Sustainable Food Systems*.

Stefanie Covino published the article “Building community resilience through nature-based solutions: What do your land use regulations encourage?” in *Massachusetts Planning*, a publication of the Massachusetts Chapter of the American Planning Association.

Abby Frazier and colleagues published the paper “A century of drought in Hawaii: Geospatial analysis and synthesis across hydrological, ecological, and socioeconomic scales” in the journal *Sustainability*.

Karen Frey is lead author of “Arctic Ocean Primary Productivity,” a chapter in the *2022 Arctic Report Card*, published annually by the National Oceanographic and Atmospheric Administration.



Robert Johnston, Tom Ndebele, and colleague David Newburn published the article “Modeling transaction costs in household adoption of landscape conservation practices” in the *American Journal of Agricultural Economics*.

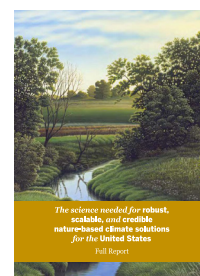
Rinku Roy Chowdhury and colleagues published the paper “Ten facts about land systems for sustainability” in the *Proceedings of the National Academy of Sciences*.

Morgan Ruelle and colleagues published the paper “Cereal species mixtures: an ancient practice with potential for climate resilience. A review” in the journal *Agronomy for Sustainable Development*.

Florencia Sangermano published the article “Acoustic diversity of forested landscapes: Relationships to habitat structure and anthropogenic pressure” in the journal *Landscape and Urban Planning*.

Surendra Shrestha (PhD Geography), **Christopher Williams**, Brendan Rogers (Woods Hole Research Center), **John Rogan**, and **Dominik Kulakowski** published the paper “Wildfire controls on land surface properties in mixed conifer and ponderosa pine forests of Sierra Nevada and Klamath mountains, Western US” in the journal *Agricultural and Forest Meteorology*.

Christopher Williams and colleagues published the report *The science needed for robust, scalable, and credible nature-based climate solutions in the United States*, the result of a workshop engaging dozens of scientists and policy experts on nature-based climate solutions.



Deborah Woodcock published the article “A typology of vessel patterning in trees with examples from the fossil record” in the *International Journal of Plant Sciences*.

About George Perkins Marsh

George Perkins Marsh (March 15, 1801–July 23, 1882) was an American diplomat, scholar of languages, and designer of buildings including the Washington Monument. As a congressman in Washington, Marsh helped to found and guide the Smithsonian Institution. He is considered by many to be America's first environmentalist. Over one hundred and sixty years ago he warned of our destructive ways in an insightful book *Man and Nature*. He was the first to raise concerns about the large-scale detrimental impact of human activities on the environment. The conventional idea held by geographers of the day was that the physical aspect of the earth was entirely the result of natural phenomena, mountains, rivers, and oceans.



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.

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GEORGE PERKINS MARSH INSTITUTE

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