



ANNUAL REPORT

2020 - 2021

Climate Negotiations

A number of Stanford scholars recently returned from Scotland for the 26th meeting of the Conference of the Parties to a global climate treaty—aka COP26—where they served on panels and engaged in other conversations exploring the connections between climate and public health, water and sanitation, the importance of blue foods and the outlook for climate adaptation. Stanford mounted one of the event’s virtual exhibits, and Woods expanded the conversation on national climate adaptation planning with an official side event that was broadcast live on screens throughout the meeting and via the COP26 YouTube channel (see inset photo, right). Woods senior fellows Chris Field (H&S, SE3) and Kari Nadeau (SOM) joined Council on Foreign Relations Senior Fellow Alice Hill for the Nov. 10 panel, which focused on progress of the annual climate summit and implications for adaptation planning, especially at the national scale.

Watch video of the event, read a related Q&A with Stanford experts and learn more about Stanford’s presence at COP26 at woods.stanford.edu/un-cop-insights/.



This page: Main photo: Chris Field, Perry L. McCarty Director of the Woods Institute (H&S, SE3), at COP26 with (from right) Kari Nadeau, Director of the Woods Institute for the Environment (SOM); Felicia Marcus, William C. Landreth Visiting Fellow at Stanford University’s Water in the West Program; and Alice Hill, Senior Fellow at the Council on Foreign Relations. **Photo Credit:** Jessica Plumb

A Word from Chris Field



We're all in this together. For me, climate change perfectly illustrates the truth of that statement. One nation's actions, for better or worse, can impact all the others. That sense of collective fate permeated this year's

global climate talks in Glasgow, Scotland. After a year when so much divided us it was a relief to gather once again (see page 2) with people from around the world who recognize the power of working in concert to tackle overwhelming challenges.

Setbacks and disagreements can make that process seem less than fruitful, but agreeing to work together is the first of many incremental steps that can lead to real progress. The Woods Institute works to create common ground for such progress through our Uncommon Dialogues and workshops. These forums provide a neutral space for researchers, policymakers, and business leaders to analyze key findings, put the issues in their broader economic, cultural, and political contexts, and develop market- or policy-based solutions.

Woods staff have been helping Stanford scholars organize these far-reaching conversations since 2004, and the outcomes have helped advance decision-making on topics ranging from California's landmark groundwater law to building coastal and wildfire resilience for greater U.S. security. In the past year we saw a truly inspiring agreement among Uncommon Dialogue participants who helped bridge a decades-long rift between hydropower interests and the conservation community. That agreement formed the basis for funding provisions related to dams and hydropower in the Infrastructure Investment and Jobs Act (see page 10).

The funding is a win for both climate and environment, providing more than \$3 billion to fund not only improvements to make more electricity but also removal of outdated dams. This Uncommon Dialogue has led directly to a very big win for the environment. It is also a prime example of how fostering dialogue can help advance policy.

This and so many more accomplishments summarized in this report illustrate how much more effective we can be when we work together. Scholars with the Center for Ocean Solutions and Center on Food Security and the Environment recently culminated three years of coordination with the Stockholm Resilience Center, EAT and 100 scholars around the world to examine the roles of food sourced from oceans, rivers and lakes in food systems and provides a scientific foundation for how best to integrate blue foods in future food systems (see page 25).

The prospect of creating a new school focused on climate and sustainability has galvanized Stanford's environmental research community in new and exciting ways over the past year (see page 4). Set for launch in fall of 2022, the school is poised to take Woods' interdisciplinary approach to solving environmental problems to the next level in partnership with our colleagues at the Precourt Institute, School of Earth, Energy and Environmental Sciences, Hopkins Marine Station, and many others at Stanford. I'm deeply grateful for the tremendous collective effort it's taken to bring us to this point and look forward to what more we'll achieve together.

Regards,

Chris Field

Perry L. McCarty Director



Director of the Sean N. Parker Center for Allergy and Asthma
Senior Fellow for Energy and the Environment with

A Foundation for Sustainability

Modern environmental challenges are too complex to be solved by any one discipline alone.

That fundamental understanding led to the development of the Ward W. and Priscilla B. Woods Institute for the Environment at Stanford 17 years ago. It also created a culture of collaboration that extends far beyond campus to Stanford-led partnerships and projects around the world.

Today, the university seeks to leverage the success of Woods' approach to collaborative problem solving by embedding Woods' knowledge-to-impact model in the foundation of Stanford's first new school in decades. With a focus on climate and sustainability, the school will marshal Stanford's dispersed teams of researchers focused on the environment, energy, and sustainable societies to form one strategically aligned, collaborative unit focused on a common goal: creating a future where humans and nature thrive in concert and in perpetuity.

A Sustainability Consensus

The call to create a new school focused on climate and sustainability at Stanford grew out of a long-range planning process that engaged more than 4,000 stakeholders and generated more than 200 proposals focused on sustainability research and education. When Stanford's new school focused on climate and sustainability begins operating in fall 2022, it will reflect the passionate consensus among students, faculty,



alumni, university leadership, and volunteers that Stanford must deepen its commitment to developing the knowledge and solutions needed to meet the world's mounting challenges.

The school's composition is based on a blueprint developed through consultation with faculty and university volunteers. Stanford President Marc

Stanford's first new school in 70 years will expand the ethos and impact of the Woods Institute for the Environment

Tessier-Lavigne selected the blueprint after he and Provost Persis Drell reviewed, and slightly modified, options provided in a report from the faculty Blueprint Advisory Committee (BAC) that developed options and recommendations for the structure of the new school. The president and provost adopted the recommendations to create a set of transitional academic divisions that will evolve into multiple departments as the school grows; initiatives organized within institutes to draw on the expertise of the entire university; and an accelerator to drive new technology and policy solutions.

President Tessier-Lavigne also supported the BAC's recommendation that the new school bring together and expand on the School of Earth, Energy, and Environmental Sciences (Stanford Earth), the Stanford Woods Institute for the Environment, the Precourt Institute

for Energy, the Department of Civil and Environmental Engineering (joint with the School of Engineering) and the facilities at Hopkins Marine Station. Additional faculty from across the university and 60 new faculty hires over the next 10 years will bring new expertise and allow Stanford to significantly expand its support of pioneering research in emerging disciplines. Many of those hires will also support a new collection of interdisciplinary, solutions-oriented initiatives that will catalyze increased scholarship and create new opportunities for impact.

Cross-cutting Initiatives

The school will include cross-cutting initiatives housed within the Woods and Precourt Institutes and within a new Institute for Sustainable Societies; some of the proposed topics those initiatives may explore include Social and Environmental Justice, Sustainable Cities, and Communications and Behavior Change. The institutes and their initiatives will be administered within the school, but their faculty affiliates and student communities will span the university and intersect with external policymakers, thought leaders and industry partners.

“The new school will be a home for a university-wide emphasis on sustainability research,” said Chris Field, the Perry L. McCarty Director of the Stanford Woods Institute for the Environment and the Melvin and Joan Lane Professor of Interdisciplinary Environmental Studies. “The sustainability of the planet affects all of us, and will require people from all backgrounds working together to create solutions.”



The Woods and Precourt Institutes have been independent institutes overseen by the Dean of Research. Within the new school, these institutes and the new Sustainable Societies Institute will house initiatives whose solutions require an integrated approach. They will fund interdisciplinary scholarship, accelerate hiring of key faculty and staff, support cross-cutting curricula and other activities to engage

undergraduate and graduate students and draw the entire university into sustainability research and education.

“Both Woods and Precourt have been extraordinarily successful at launching new research teams in energy and the environment, and their impact can be felt through new policies their work has inspired, and technologies that improve our lives,” said Kam Moler, Vice Provost and Dean of Research and the Marvin Chodorow Professor of Physics and Applied Physics. “Within the new school they will be critical for the university-wide mission for the school and their impact can be even greater. They will be able to inspire faculty hires in areas critical for the initiatives, and can contribute to curricula that train students in interdisciplinary approaches to sustainability.”

Collaborative Research

Stanford engineers, physicians, sociologists, Earth scientists and others soon will collaborate to make cities healthier, revolutionize plastic recycling, track and treat viruses in water, combat the illegal wildlife trade and more.

This year the Stanford Woods Institute for the Environment awarded more than \$1.5 million to 10 innovative projects as part of its 2021 [Environmental Venture Projects \(EVP\)](#) and [Realizing Environmental Innovation Program \(REIP\)](#) grants. Both programs provide up to \$200,000 per project for interdisciplinary research needed to solve major environmental challenges too complex for any one discipline alone to tackle.

Since EVP began in 2004 and REIP began in 2015, the Stanford Woods Institute has awarded more than \$19 million in grants to 122 research teams representing all seven of Stanford's schools and working in 33 different countries. These projects have gone on to receive more than \$47 million in additional funding from other sources. Read on for details about this year's awards and highlights from projects that already are up and running.

Environmental Venture Projects (EVP)

EVP grants support interdisciplinary, high-risk research projects that identify and develop real-world solutions. The projects selected for 2021:

IMPROVING PLASTIC WASTE MANAGEMENT

Globally, 359 million tons of plastic waste are generated annually. It is estimated that 150-200 million tons accumulate in the natural environment each year. This project aims to radically change the way plastic waste is processed via a new biotechnology paradigm: engineering highly active enzymes and microbes capable of breaking down polyesters in a decentralized network of "living" waste receptacles. In parallel, the researchers are building a quantitative model of human behaviors involved in plastic recycling and are in active dialogue with leading apparel companies, to explore options for a venture that can scale and bring the technology to market.

Jennifer Cochran (Bioengineering), Craig Criddle (Civil and Environmental Engineering) and Erin MacDonald (Mechanical Engineering)

PROTECTING WOMEN'S HEALTH

Exposure to heavy metals in the environment is a pressing environmental health threat, particularly in low- and middle-income countries. This project aims to identify the sources of metal exposure among pregnant women in Faridpur, Bangladesh,

and the potential role of this exposure in contributing to the elevated rate of stillbirth. To do this, the researchers will leverage the framework of an ongoing child health and mortality prevention surveillance study to compare placental biomarkers of metal exposure among stillbirths and live births. The team will evaluate concentrations of various metals in drinking water, soil, rice, and turmeric to identify the likely routes of exposure to metals during pregnancy. This research will inform interventions to reduce women's exposure to metals and may identify pathways connecting environmental metals to stillbirth.

Steve Luby (Medicine), Gary Shaw (Pediatrics) and Scott Fendorf (Environmental Earth System Science)

TRACKING AND TREATING VIRUSES IN WATER

The vast majority of research on human viruses is focused on viruses in the human body; the literature is relatively void of data on virus persistence in the environment. This project aims to fill that void by carrying out novel research on virus persistence in water. The work will focus on two important groups of viruses: one of the most important etiologies of gastrointestinal illness in the world—human norovirus (HNoV)—and the subfamily of viruses responsible for the COVID-19 pandemic—human coronaviruses (HCoVs). The researchers will study the persistence of infectious HNoV in water, a subject which has not been studied previously owing to methodological limitations on cultivation of the

virus. They will also study the persistence of CoVs including SARS-CoV-2 in water and wastewater as well as their potential for disinfection by free chlorine. The results from this work will have immediate applications to inform de facto wastewater reuse and recreational water quality standards.

Ali Boehm (Civil and Environmental Engineering), Catherine Blish (Microbiology and Immunology), Harry Greenberg (Microbiology and Immunology) and William Mitch (Civil and Environmental Engineering)

IMPROVING CLIMATE CHANGE MESSAGING

Social and behavioral scientists have identified several approaches to climate change communication that increase belief in, and/or concern about, the phenomenon. However, the applicability of this research suffers from its lack of organization, incommensurable measures and sampled populations, and often very under-powered empirical tests. These challenges limit the practical value of this research for scientists, policymakers, educators and advocates seeking to build popular support for efforts to address climate change. To resolve these issues, this project will create a large-scale experimental tournament of 12 promising climate change messaging approaches. Results of the tournament will be driven to practice through broad media engagement, open seminars with advocacy groups, targeted outreach to leadership in major environmental organizations, and a virtual conference for climate change scientists, journalists, and activists.

Rob Willer (Sociology), Neil Malhotra (GSB) and Jane Kathryn Willenbring (Geologic and Environmental Science)

MONITORING GAS POLLUTION IN THE ARCTIC

Gas sensing in remote regions and in our oceans is becoming increasingly important for developing mitigation strategies and policies in response to global warming. This project will develop a monitoring strategy based on inexpensive, passive and biodegradable sensors, which can be distributed in the environment without detrimental effects, combined with optical spectroscopy. The sensors are placed in corner-cube arrays that acts as retroreflectors, whose signals are remotely detected by spectroscopic interrogators that can be placed in stationary base stations or on movable platforms, e.g. airplanes and drones. The research has a dual focus of developing the sensor technology and the deployment strategy.

Olav Solgaard (Electrical Engineering) and David Reis (Applied Physics)

MEASURING SOIL MOISTURE FROM SPACE

Soil moisture is a key variable in understanding both the global water cycle and the local movement of water in agricultural or ecologically-sensitive areas. Present methods of measuring water content remotely are very coarse, mostly at tens of kilometers resolution, and therefore do not satisfy the needs of the agricultural industry. This project will develop a new method of analyzing spaceborne radar

data at 10m resolution to meet this added need. Using a variety of satellite data, the researchers plan to test a new processing and analysis approach to yield estimates of soil moisture at finer resolution than is possible with current remote methods.

Howard Zebker (Electrical Engineering) and Alexandra Konings (Environmental Earth System Science)

Realizing Environmental Innovation Program (REIP)

REIP is intended to forward solution-based projects from the discovery phase of research to the validation phase and adoption by end users. The projects selected for 2021:

SUSTAINING THE UPPER COLORADO RIVER

The Colorado River basin supplies water to 40 million people and 5.5 million acres of farmland, and it provides critical in-stream and riparian habitat. Yet, water law historically reserved no water for riverine ecosystems. Today, the basin's rivers routinely run so low that severe ecological damage to fish habitat occurs, with 44 of 49 native fish species endangered, threatened or extinct. Buying water to protect ecosystems through private water rights transactions—a proven market mechanism to restore river flows—entails conservation buyers pursuing individual water sellers on a mostly ad hoc basis instead of exercising an optimal, cost-effective regional strategy. This project aims to deploy a novel

Collaborative Research

ecohydrologic-economic-legal model that optimizes ecological preservation. The model identifies the most beneficial set of surface-water market transactions for ecosystems in the Upper Colorado River basin. Focusing on Colorado, this model will inform water-rights markets and help conservation organizations to maximize fish habitat restoration with their existing financial budgets.

Steve Gorelick (Environmental Earth System Science) and Buzz Thompson (Law)

COMBATTING THE ILLEGAL WILDLIFE TRADE

The illegal wildlife trade (IWT) is at least a \$23 billion/year industry that is greatly reducing biodiversity, degrading ecosystem functions, threatening the world with emerging infectious diseases, and is closely linked to human trafficking, regional destabilization and terrorism. A key limitation in the fight against IWT is an inability to identify where animal materials are coming from and distinguish between legal and illegal products. This project will address this limitation by capitalizing on current genomics technology, new collaborations within the Stanford community and research strides already made to develop a tool to identify the geographic origin of confiscated materials inexpensively and in-country. To prototype this tool, the researchers will focus on African lions in partnership with two government agencies (U.S. Fish and Wildlife Service and the

South African National Biodiversity Institute) and three NGOs (African Parks, Wildlife Conservation Society and Panthera). Through these partnerships, the information generated will be used to identify and disrupt trafficking routes, strengthen law enforcement, and implement community engagement responses.

Dmitri Petrov (Biology) and David Relman (Microbiology and Immunology)

EMPOWERING SMALL-SCALE FISHERS

Small-scale fisheries and supply chains support livelihoods and nutrition for millions of people, particularly in low- and middle-income countries. Around the world, fisheries supply chains are becoming increasingly digitized, creating faster and more reliable avenues of market access for small-scale fishers. However, it is not yet understood if these technologies improve fishers' livelihoods and influence fishers' decision-making. This project will investigate these questions through the deployment of a well-established digital platform by ABALOBi with fishers in the Republic of Palau. Using a quasi-experimental design, the researchers will track socioeconomic and decision-making metrics before, during, and after deployment of the ABALOBi app, generating actionable and scalable insights into the role of technological interventions in empowering small-scale fishers and promoting sustainable solutions for fishing communities.

Gabrielle Wong-Parodi (Environmental Earth System Science), Michael Bernstein (Computer Science) and Fiorenza Micheli (Biology)

MAKING CITIES HEALTHIER

With over half of humanity living in cities today, three critical trends collide: 1) urbanization reduces experience of nature; 2) sedentary, nature-deprived urban lifestyles increase already massive health burdens and risks; and 3) highly uneven access to nature exacerbates multiple inequalities. Yet, the connections between urban nature and health remain woefully understudied. Revealing where and how nature provides greatest benefits to people can inform and motivate investments in urban design with nature. This unique interdisciplinary team will integrate a wealth of new data, science and analytics—through both physical and mental health pathways—as well as deep relationships with urban leaders and networks. By developing actionable science and demonstrating the findings for three iconic cities—San Francisco, Guangzhou and Singapore, this project is designed to inform urban planning and policy, enhance urban nature and its vital benefits, and improve health, equity, livability, and the sustainability of cities.

Gretchen Daily (Biology), Abby King (Epidemiology and Public Health) and Kari Nadeau (Pediatrics)

2020-21 Highlights

AI FOR CLEAN WATER

How can cutting edge data science help protect the environment? That question is at the heart of this 2020 REIP-funded project focused on pioneering machine learning methods that can help the U.S. EPA increase Clean Water Act compliance and, ultimately, tackling a range of environmental compliance challenges. The team's findings, published this past March in the proceedings of the Association of Computing Machinery Conference on Fairness, Accountability and Transparency, reveals how two key elements of so-called algorithmic design influence which communities are targeted for compliance efforts and, consequently, who bears the burden of pollution violations.

REIMAGINING WASTEWATER

Many agricultural regions of the world require a sustainable supply of surface water and / or groundwater. Massive groundwater extraction in California's Central Valley has created large, unused groundwater storage spaces—an opportunity for a form of managed aquifer recharge (MAR) in which excess surface water from winter storms or spring snowmelt is allowed to move into the subsurface and recharge the groundwater system. With funding from a 2019 REIP grant, Stanford researchers have been developing a novel methodology using 3D images of sediment

texture in the subsurface to assess site suitability for the approach. The project recently received a \$10 million USDA grant led by UC Davis and will receive funding as part of California's Senate Bill 170, which allocates \$60 million for floodplain restoration projects.

MUSKRATS AS BELLWETHER

Climate change and human activities such as hydropower development have created ecological impacts and habitat loss at the Peace-Athabasca Delta in northeastern Alberta, Canada, a UNESCO World Heritage Site. With funding from a 2016 EVP grant, Stanford researchers have been exploring the effects of climate change and human activity on the inland delta—on of planet's largest—in order to help understand, mitigate and adapt to ecohydrologic changes and preserve biodiversity in this and other parts of the world. The team's research, published in Communications Biology this past June, suggests long-term drying is making it harder for muskrats to recover from massive die-offs—a sign of threats to come for many other species.

BRICK KILNS

Brick kilns in Bangladesh and throughout South Asia produce damaging air pollution, accounting for a large percentage of particulate matter (PM2.5) emissions, which can cause cardiovascular and respiratory disease and even death. With funding from a 2016 EVP grant, Stanford researchers have been working

on a range of approaches to help stakeholders in the public, private, and community sectors make the sector less harmful to human health and the environment. This past April, the BBC featured the team's research into using AI to identify illegally operating kilns.

LEAD CONTAMINATION

Human exposure to lead in the environment causes irreversible impairment of intellectual function. In Bangladesh, where some rural residents have unexpectedly high levels of lead in their blood, the source has proven difficult to pinpoint. With funding from a 2013 EVP grant, Stanford researchers have been evaluating the severity of lead poisoning in rural Bangladesh and identifying the pathway of exposure to help develop focused prevention strategies around the world. The team's study, published this past March in Environmental Research, finds that a relatively affordable remediation process can almost entirely remove lead left behind by unregulated battery recycling—an industry responsible for much of the lead soil contamination in poor and middle-income countries—and raises troubling questions about how to effectively eliminate the poison from children's bodies.

Compelling Conversations

So much can be gained from a conversation. Over the past year, top experts, leaders and practitioners have visited Stanford virtually to discuss their field shaping work on climate and environmental issues as well as their career journeys, allowing our community of scholars, students and the public to connect with the people positioned to solve big problems and how they got there. These stirring dialogues covering a range of environmental policy and science issues provide a bridge across disciplines to engage with different perspectives on some of the world's toughest sustainability challenges.

“Access to clean water is such a fundamental basic service and many Americans take it for granted.”

—Anne Castle

CONVERSATION WITH MARCENE MITCHELL

“There’s no going it alone in the climate area. We talk a lot about the whole of society



addressing the climate crisis. It cannot only be national governments. It needs to be the business community, the academic community, the sub-nationals—lots can be done at the state and local level—and we need to have individuals participating.”

Marcene Mitchell, senior vice president of Climate Change at the World Wildlife Fund, speaking on Oct. 20, 2021.

CONVERSATION WITH ANNE CASTLE

“Access to clean water is such a fundamental basic service and many Americans take it for granted. And so it comes as a surprise to most Americans



that some of our neighbors on Native American reservations don’t have that basic commodity.”

Anne Castle, Senior Fellow at the Getches-Wilkinson Center for Natural Resources at the University of Colorado and former Assistant Secretary for Water and Science at the U.S. Department of the Interior, speaking in a conversation hosted by Stanford’s Water in the West Program on Sept. 16, 2021.

Learn more: <https://stanford.io/3l1oIWm>

CONVERSATION WITH DEBRA ROBERTS

“I’m the first local government practitioner who’s ever been a co-chair of the IPCC. Two focal areas leapt out to me: how do I improve the awareness of the IPCC in Africa; and how do



we bring forward an awareness amongst those people who actually drive change at the local government level.”

Debra Roberts, head of the Sustainable and Resilient City Initiatives Unit in the eThekweni Municipality (Durban, South Africa) and Co-Chair of Working Group II for the Intergovernmental Panel on Climate Change (IPCC), speaking on May 6, 2021.

Recap: <https://stanford.io/3CLrD6l>

CONVERSATION WITH HILARY TOMPKINS

“I think a lot of legal issues and conflicts and issues about restoring, healing, and reconciliation is very similar to that Navajo principle of

Hózhó, so I used that a lot in my work when I could see a new challenge. How can we restore balance and peace to this situation?”

Hilary Tompkins, Partner at Hogan Lovells and former solicitor of the U.S. Department of the Interior, speaking on April 21, 2021.

Recap: <https://stanford.io/3HJcEO3>

CONVERSATION WITH PAT BROWN

“I just challenged myself to figure out how I can have the biggest positive impact on the world, given the kinds of things that I’m competent at doing. And I figured it would probably



have something to do with addressing global environmental issues since I feel like that’s the biggest determinant of the future of humans and our planet.”

Pat Brown, CEO of Impossible Foods speaking on Mar. 11, 2021.

Recap: <https://stanford.io/2Zhra4>

N. H. SCHNEIDER MEMORIAL LECTURE: DR. AYANA ELIZABETH JOHNSON

“If environmental justice is a field, then we lose.



We have to include justice in our work, no matter where we work, or what we call it.”

Ayana Elizabeth Johnson, founder of Urban Ocean Lab, speaking on Feb. 18, 2021.

Recap in the Stanford Daily: <https://bit.ly/3xcqNyc>

BILL GATES: HOW TO AVOID A CLIMATE DISASTER

“We’ve got to enlist everyone in this very, very hard work. It’s not just one breakthrough... The key point of the book is you have to have solutions across all spaces.”

Bill Gates, co-chair of the Bill & Melinda Gates Foundation and founder of Breakthrough Energy, speaking about his book *How to Avoid a Climate Disaster* in a conversation jointly hosted by the Woods Institute and the Precourt Institute for Energy on Feb. 18, 2021.

Recap: <https://stanford.io/3kZabVK>

CONVERSATION WITH STEVEN CHU

“If you want to get something done, take responsibility. It’s the old saying, success has many fathers and mothers but failure’s an orphan. In order to get things done, the buck stops wherever it stops.”



Steven Chu, the William R. Kenan, Jr., Professor of Physics and Professor of Molecular & Cellular Physiology at Stanford and former secretary of energy, speaking on Jan. 21, 2021.

Recap: <https://stanford.io/3DL5gPQ>

NATURAL CAPITAL PROJECT CONVERSATIONS

Stanford’s Natural Capital Project hosted a series

of conversations bringing together experts to discuss water-related and land-based cultural services that nature provides to people, nature-based solutions and water, climate-smart coastal planning and sustainable development, natural infrastructure in urban planning, land-use planning in the Amazon, nature in economics, nature and urban solutions, and the Anthropocene ocean.

Learn more: <https://stanford.io/3pbh6Nd>

APPROACHING SUSTAINABILITY: CONVERSATIONS WITH LEADING SCHOLARS

Gabrielle Wong-Parodi, assistant professor of Earth System Science, led a seminar series featuring distinguished scholars from UC Berkeley, Carnegie Mellon University, and other institutions on the future of sustainability research and education aimed to inspire, inform, and spark discussion about how we develop sustainability research and education at Stanford.

Learn more: <https://stanford.io/3CISkbQ>

WATCH + TALK FEATURING “EXTINCTION: THE FACTS”

The BBC film “Extinction: The Facts” explains the extinction crisis and highlights the growing threats to the world’s species. A panel discussion featuring Stanford Biology Professor Elizabeth Hadly, who was interviewed for the BBC production, as well as Stanford Biology Professors Rodolfo Dirzo, Paul Ehrlich, and Chris Field, explored themes in the film including biodiversity loss, zoonotic disease, habitat destruction, and the impact of population rise on the natural systems.

Recap: <https://stanford.io/2ZfCFmL>

Uncommon Dialogues

A Woods-convened negotiation between the hydropower industry and environmental community—two factions at odds for decades—led to a breakthrough agreement in 2020. Recommendations resulting from that process guided federal lawmakers in the bipartisan U.S. infrastructure legislation, signed by President Biden in November, to invest more than \$3 billion in the rehabilitation, retrofit or removal (the “3Rs”) of the more than 90,000 U.S. dams.



Parties to the agreement were motivated by two urgent challenges. To decarbonize the nation’s electricity system, they recognized the role that U.S. hydropower plays as an important low-carbon energy resource as well as a significant means to integrate variable solar and wind power into the U.S. electric grid. At the same time, the nation’s rivers, and the biodiversity and ecosystem services they sustain, are vulnerable to the compounding factors of a changing climate, habitat loss and alteration of river processes. The shared task of the diverse parties was to chart hydropower’s role in a clean energy future in a way that also supports healthy rivers.

The agreement was the product of a Woods “Uncommon Dialogue” convening process, which brings together multi-sector stakeholders and experts to address significant environmental challenges. Uncommon Dialogues, a part of Woods work since the institute’s founding, allow leaders from different sectors to explore potential solutions in a neutral setting with facilitation by Stanford experts. The dialogue that catalyzed the 2020 agreement—“Hydropower: Climate Solution and Conservation Challenge”—was led by Woods Senior Research Scholar Dan Reicher, a former U.S. Assistant Secretary of Energy, Director of Climate Change and



Energy Initiatives at Google, board member of American Rivers and the American Council on Renewable Energy, and a director at the Climate Adaptive Infrastructure Fund.

Reicher brought his contacts in the conservation and renewable energy

world together at Stanford in March 2018 to begin the two-and-a-half year negotiation. Working in conjunction with Stanford’s Steyer-Taylor Center for Energy Policy and Finance, where Reicher was the founding executive director, and the Energy Futures Initiative, led by former U.S. Secretary of Energy Ernest Moniz, Reicher assembled participants from industry, government, NGOs and academia to envision how to best increase the ability of U.S. dams to provide clean energy and electricity storage while improving dam safety and the environmental quality of the nation’s rivers.

The agreement was built around the “3Rs” of the nation’s 90,000+ dams: rehabilitate some for

safety; retrofit some for power production and to cut their environmental impact; and remove some for conservation and dam safety. The parties were compelled by some important facts: only about 2½ percent of U.S. dams generate electricity and powering a number of non-powered dams can add significantly to the nation's low-carbon electricity; 90% of today's U.S. electricity storage is provided by "pumped-storage hydropower" and more is being developed; and the 3Rs can be implemented on a "basin-scale", as demonstrated on Maine's Penobscot River in Maine, where between 2006 and 2016 multiple dams were removed, retrofitted and rehabilitated resulting in the return of key fish species, safer operations, and with no reduction in electricity generation and improved relations among NGOs, native tribes and power companies.

Following the October 2020 agreement, signatories invited other key stakeholders, including tribal governments and state officials, to join the collaboration, and to address implementation priorities, decision-making, timetables, and resources. One key opportunity reflected newly-elected President Biden's commitment to securing major new funding for U.S. infrastructure. Realizing the potential this represented for U.S. dams—a core piece of the

nation's infrastructure—the parties went back to the table. In April 2021 they reached a second agreement which laid out the \$63 billion needed to substantially address the 3Rs of the nation's 90,000-plus dams.

"Complex environmental issues affect and are affected by people with so many different concerns—just the process of finding common ground can take a long time," said Lea Rosenbohm, Woods' associate direc-



Alewives are making a comeback after dam removals on Maine's Penobscot River. Credit: Michael Wilson

tor for policy and engagement, who has played a lead role in the organization of many Woods Uncommon Dialogues. "The fact that

recommendations from this series of conversations have been included in bipartisan federal legislation is really a testament to Dan Reicher's vision and commitment and demonstrates the importance of bringing diverse voices to the table to make tangible progress."

Participants who joined the effort represented a diverse range of organizations, companies, tribes, government agencies and universities, notably including the National Hydropower Association, on behalf of U.S. hydropower companies, and American Rivers, the Nature Conservancy, the Union of Concerned Scientists and the World Wildlife Fund, on behalf of the U.S. environmental community.

"It was a risky idea and a heavy lift but it is exciting to see our breakthrough 3Rs agreement turned into a significant federal down payment on the massive funding needed—measured in the tens of billions of dollars—to address serious problems and major opportunities at the nation's dams," Reicher said.

Read more about the Uncommon Dialogue on hydropower and river conservation, its outcomes and related coverage at: <https://woods.stanford.edu/research/hydropower>

Accessible Insights

Fostering dialogue between scholars, stakeholders and the public is key to cultivating innovative ideas, policies and technologies to improve sustainability. Over the past year, Stanford scholars joined other experts, practitioners, industry professionals and stakeholders to discuss policies, practices, and potential solutions to pressing environmental challenges. From wildfires to snow storms, virtual webinars featuring a diversity of perspectives provided our community with new insights on health, wildfire, infrastructure and other pressing topics.



Wildfire Impacts and Prevention

NEW EVIDENCE ON THE HEALTH IMPACTS OF WILDFIRE SMOKE

How are wildfires impacting the health of people in our region from the individuals helping to fight the fires to the millions exposed to polluted air? In a virtual panel discussion, Stanford professors Kari Nadeau, Marshall Burke, Lynn Hildemann, and Chris Field explored new evidence of wildfire smoke impacts and what effective responses from policymakers, governments, and individuals might look like.

WILDFIRE AND HEALTH: IMPACTS ON THE MOST VULNERABLE

Smoke from wildfires disproportionately impacts vulnerable populations, such as children, pregnant women, and under-resourced communities. The Center for Innovation in Global Health's Action Lab for Planetary Health (ALPHA) and the Woods Institute hosted a webinar with Stanford researchers Marshall Burke, Mary Prunicki, Lisa Patel, and Michael Wara, and Amee Raval, Policy & Research Director of the Asian Pacific Environmental Network experts to discuss the latest research highlighting the urgent need for investment in infrastructure that decreases vulnerable populations' smoke exposure and increases wildfire prevention strategies.

A NEW STRATEGY FOR ADDRESSING THE WILD-FIRE EPIDEMIC IN CALIFORNIA

California is investing significant funds to fight the state's devastating wildfires, but is it enough? In a virtual panel discussion, Michael Wara, director of the Climate and Energy Policy Program at the Woods Institute, presented a new working paper on needs for



wildfire risk reduction funding in California. He was joined by Nancy Watkins, principal and consulting actuary at Milliman, Crystal Kolden, assistant professor at UC Merced, and Laura Tam, program officer at the Resources Legacy Fund, who offered their perspectives on the scope and scale of public and private investments needed to make a difference on such a massive challenge.

Infrastructure



THE HIDDEN ELEMENT: WATER'S VITAL ROLE IN ECONOMIC RECOVERY

In the national conversation about infrastructure, water is one of the most overlooked systems. Newsha Ajami, Director of Urban Water Policy at Water in the West, joined experts Joseph Kane, Senior Research Associate at The Brookings Institute, Alesandra Najera, Program Officer at the Water Foundation, and Hannah Northey, Reporter with E&E News, in a webinar to explore the frequently hidden but critical role water infrastructure can play in the recovery from the COVID-19 pandemic. A follow-up to this discussion appeared in The Avenue, The Brookings Institute's blog focused on metropolitan policy.

FEBRUARY'S DEEP FREEZE: CASCADING DISASTERS IN AN ERA OF CLIMATE DISRUPTION



In February 2021, Texas experienced massive winter storms with devastating human and economic impacts, disrupting electricity, gas, water, and food supplies and causing significant water and other damages to homes and businesses. In an online conversation, Stanford professors Sarah Fletcher, Arun Majumdar, Michael Wara, and Chris Field and Catherine Coleman Flowers, Founder of The Center for Rural Enterprise and Environmental Justice,

addressed the causes and consequences of this cascade of failures, including the relevance for infrastructure and disaster risk reduction in the future; who pays and manages costs; adaptation and resiliency planning; and lessons about interactions with inequality and racism.



DECARBONIZATION AND NATURAL GAS RATES: COST-EFFECTIVE, EQUITABLE PATHS TO ZERO CARBON BUILDINGS

The use of natural gas makes California's buildings a significant source of GHG emissions. To meet climate targets, the state needs to decarbonize buildings but that can have negative impacts on ratepayers, raising equity concerns. In a webinar, Stanford researchers Mike Mastrandrea, Research Director of the Climate and Energy Policy Program, Alison Ong, graduate student in the Emmett Interdisciplinary Program in Environment and Resources, and Michael Wara presented new research estimating rate impacts to residential natural gas customers from currently proposed building decarbonization policies as well as the GHG emission impacts of those policies.

Accessible Insights



Climate and COP26

CLIMATE CHANGE ACTION: THE ROLE OF NATURAL SOLUTIONS

Land stewardship alone could provide about 30% of the global cost-effective solution to climate change, explained Bronson Griscom, senior director for natural climate solutions at Conservation International during a virtual panel discussion focused on the role of natural climate solutions: nature-based methods for safely capturing and storing greenhouse gases (GHGs). He was joined by Asmeret Asefaw Berhe, professor at UC Merced, Rebecca Chaplin-Kramer, lead scientist for Stanford's Natural Capital Project, and Director Chris Field.

THE PATH TO ZERO NET GHG EMISSIONS BY 2050

The United States rejoined the Paris Climate Accord on February 19 and the nation must now find specific targets and a mix of technologies, policies, incentives, regulations, and philosophies that enable America to meet those targets. In a webinar featuring Director Chris Field, Mark Jacobson, Professor of Civil and



Environmental Engineering, Dan Reicher, Senior Research Fellow at Woods and a former assistant secretary of energy, and Stephanie Roe, Researcher at the University of Virginia, experts discussed the status of clean energy technology production and the options for carbon removal, especially by nature.

COP26: HOPES, EXPECTATIONS, FEARS

In advance of the negotiations at the United Nations' Climate Change Conference (COP26) in Glasgow, Scotland, Stanford professors and climate experts Chris Field and Rob Jackson joined Catherine Coleman Flowers and Cathy Luo, Co-Director of Students for a Sustainable Stanford, in an online conversation about hopes, fears, and expectations for the talks now that the United States has reentered the Paris Agreement.



COP26: TOWARD NATIONAL ADAPTATION PLANNING

In an Official COP26 Side Event, Director Chris Field joined Kari Nadeau and Alice C. Hill, Senior Fellow for Energy and the Environment at the Council on Foreign Relations, in Glasgow to discuss the progress of the negotiations, what it means for climate adaptation planning going forward, and why it is so important to have a national adaptation strategy.



United Nations
Climate Change



UN CLIMATE CHANGE
CONFERENCE UK 2021

Research Centers & Programs

The Stanford Woods Institute for the Environment supports strategic research centers and programs designed to tackle major environmental challenges facing the planet. These interdisciplinary initiatives leverage Stanford's particular strengths to solve cross-cutting sustainability challenges at the intersection of climate change, food security, freshwater and public health and the demands of a growing population on the natural systems that support life on earth. Read on for selected 2020-21 highlights and publications from our hosted centers and programs.

Climate and Energy Policy Program (CEPP)

CEPP operates at the interface of policy analysis, academic research and education and stakeholder engagement. By collaborating with external partners in the government, private and nonprofit sectors, the program offers Stanford students and faculty an opportunity to directly engage with and solve real energy and climate policy problems while integrating interdisciplinary research with direct policy engagement.

Faculty Director: Chris Field

[woods.stanford.edu/
climate-and-energy-policy-program/overview](https://woods.stanford.edu/climate-and-energy-policy-program/overview)

HIGHLIGHTS

- As wildfires raged in the West, CEPP Director Michael Wara produced a white paper, [“A New Strategy for Addressing the Wildfire Epidemic in California,”](#) outlining a strategy to address



wildfire risk reduction funding in California. The proposal focuses on investment in structure hardening to make buildings more resistant to ignitions, enhancing community-level protections from wildfire, managing public and private landscapes at scale using ecologically oriented fuels management and prescribed fire, and restructuring responsibilities for fire management to improve clarity and fiscal commitment at sufficient scale. Initially presented as part of a Woods [webinar](#), elements of this work were included in California's [SB 332](#), which adds legal protections for those who implement prescribed burns for public benefit, and [AB 642](#), which establishes a prescribed fire training center and requires CAL FIRE to appoint a cultural burning liaison.

- California's buildings are a significant source of greenhouse gas emissions due to their utilization of natural gas, but building decarbonization strategies can have significant ratepayer impacts, raising equity concerns. Research by Alison Ong, Ph.D. student in the Emmett Interdisciplinary Program for Environment and Resources, with CEPP Research Director Michael Mastrandrea, and Wara quantified potential increases in residential natural gas rates associated with building decarbonization approaches being considered by California policymakers. Their study warns that many options pose serious

long-term affordability challenges to consumers, exacerbating existing affordability issues for lower income communities. The research team discussed their findings in a [webinar](#), and presented their white paper “[The Costs of Building Decarbonization Policy Proposals for California Natural Gas Ratepayers: Identifying Cost-effective Paths to a Zero Carbon Building Fleet.](#)”



- The California State Assembly Committee on Utilities and Energy hosted an informational hearing “Beyond New Construction: Decarbonizing California’s Existing Building Stock,” which delved into the many issues, barriers and opportunities surrounding the state’s move to reduce fossil fuel emissions in the housing and building sectors. The hearing featured a panel of experts, including Wara, who explained that looking for opportunities within the gas system to avoid investments that are upcoming, selecting areas where decommissioning

could occur and assisting homeowners and commercial entities to make the transition should be top priorities.

- CEPP also fostered active collaborations with government, private and nonprofit entities, including Resources Legacy Fund, CA Environmental Justice Alliance, CA Public Utilities Commission, Legislative Analyst’s Office, The Greenlining Institute and the CA Office of Planning and Research, working on different topics from environmental justice to climate financial risk.

CEPP PUBLICATIONS

The Costs of Building Decarbonization Policy Proposals for California Natural Gas Ratepayers: Identifying Cost-effective Paths to a Zero Carbon Building Fleet. *Climate and Energy Policy Program*

The changing risk and burden of wildfire in the United States. *Proceedings of the National Academy of Sciences*

Accounting for the Greenhouse Gas Emission Intensity of Regional Electricity Transfers. *Environmental Science and Technology*

A New Strategy for Addressing Wildfire Epidemics in California. *Climate and Energy Policy Program*

Center for Ocean Solutions (COS)

COS is focused on creating innovative solutions to pressing challenges facing the ocean. The center catalyzes research, innovation and action to improve the health of the oceans for the people who depend on them most.

Co-Directors: Jim Leape, Fiorenza Micheli

oceansolutions.stanford.edu/

HIGHLIGHTS

- Building on COS research to support the implementation of Palau’s National Marine Sanctuary, Palau’s new President invited the Center to provide science and policy analyses that explore the interlinked challenges of conservation, food security and economic recovery. COS and Palauan collaborators are developing training materials for sanctuary



monitoring, investigating digital platforms to empower small-scale fishers, and optimizing eDNA detection in marine waters. COS also received a \$2 million award from the Global Environment Facility to strengthen marine resource management across Micronesia.

- COS is working with governments, NGOs and seafood companies to close the Pacific Ocean to illegal fishing. This year, COS brought industry leaders together in a commitment to transparency in seafood supply chains. COS is also working globally to map the risks of illegal fishing and labor abuse at port and at sea and help leading companies address risks in their supply

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chains. In addition, the Center is developing computer vision techniques to detect 'dark' vessels and illuminate illegal fishing activities.

- COS and the Stanford Center for Human Rights and International Justice are collaborating with the Indonesia Ocean Justice Initiative to address labor abuses in the seafood sector. The Centers are working with the International Seafood Sustainability Foundation and four of its member companies to explore the potential for a platform that could increase transparency and accountability when workers are recruited onto vessels in tuna supply chains.
- COS has partnered with leading research institutions and aquariums to lead [Ocean Visions](#), a consortium that fosters collaboration among researchers, conservationists and entrepreneurs to solve ocean challenges. Ocean Visions convened panel sessions at the inaugural Ocean Sciences Meeting last February and has established an ocean solutions section in *Frontiers of Marine Science*. COS Co-Director Micheli, a member of the Ocean Visions leadership team, has also co-authored articles and reports on ocean-based climate solutions to address hypoxia, marine heat waves, and deoxygenation.
- COS worked with the Center on Food Security and the Environment and partners with EAT and the Stockholm Resilience Center to launch the Blue Food Assessment, a global analysis on the diversity of blue foods

and the role they can play in transforming our food system. Read more at right.

PUBLICATIONS

Tuna fisheries bycatch and climate change in the western tropical Pacific Ocean. *Western and Central Pacific Fisheries Commission*

Quantitative PCR assays to detect whales, rockfish, and common murre environmental DNA in marine water samples of the Northeastern Pacific. *PLoS ONE*

Promoting equity in scientific recommendations for high seas governance. *EcoEvoRxiv*

Persistent gender bias in marine science and conservation calls for action to achieve equity. *Biological Conservation*

Sustainable fisheries are essential but not enough to ensure well-being for the world's fishers. *Fish and Fisheries*.

A review of a decade of lessons from one of the world's largest MPAs: conservation gains and key challenges. *Marine Biology*

Identifying predictors of international fisheries conflict. *Fish and Fisheries*

Ocean acidification causes variable trait-shifts in a coral species. *Global Change Biology*

Incorporating blue carbon sequestration benefits into sub-national climate policies. *Global Environmental Change*

Establishing the Foundation for the Global Observing System for Marine Life. *Frontiers in Marine Science*

to examine the role of 'blue' or aquatic foods in global food systems. The Assessment launched this year as decision-makers around the world convened to chart the future of food systems in the UN Food Systems Summit and other venues.

The first five Blue Food Assessment papers were published in various Nature journals, including a cover feature on Nature's weekly print edition. Key findings were summarized in a report for decision-makers and shared one week before the Summit that synthesized the first five papers as well as four that are forthcoming. The report provides decision-makers with scientific insights on opportunities, challenges and tradeoffs so they can implement policies that will benefit both people and the planet. Five action briefs were also published with specific findings and recommendations tailored for decision-makers in public health, development, environment, retail and food service, and blue food companies.

Nature also published an editorial, podcast and 'immersive' web page dedicated to blue foods. The Assessment premiered a global broadcast the following day that included a presentation from the Assessment's co-chairs; a stakeholder panel moderated by Nature's editor-in-chief; shoutouts from 'blue' celebrities and political figures; a keynote address from Peru's former Minister of Production; and closing remarks from the Director of the Wildlife Conservation Society's Fiji Country Program.

The Blue Food Assessment led a session at the Pre-Summit devoted to blue food featuring seven Member States and leaders from the UN, including the UN Secretary General's Special Envoy for the Food Systems Summit and Special Envoy for the Oceans. The Summit later featured a proposed coalition on blue foods that was developed with various partners and supported by 22 Member States. Grounded in previous international collaborations, the coalition aims to mobilize action across the blue food sector to build more resilient food systems.

Learn more about the Blue Food Assessment at <https://bluefood.earth/>

The Blue Food Assessment

Can food sourced from the ocean, lakes and rivers contribute to healthier, more sustainable and more equitable food systems? A coalition of researchers led by Stanford researchers and their colleagues with the Stockholm Resilience Centre and EAT set out in 2019 to answer that question and more with The Blue Food Assessment. It is both an ambitious series of peer-reviewed papers and an evolving partnership drawing on the combined expertise of more than 100 scholars. Stanford's Center for Ocean Solutions and the Center for Food Security and the Environment designed the project

Program for Disease Ecology, Health and the Environment (DEHE)

The DEHE program, a joint initiative with Stanford's Center for Innovation in Global Health, draws on Stanford experts in public health, technology, engineering, computer



science, medicine and the social sciences to discover ecological solutions to humanity's health challenges and to develop the next generation of planetary health innovators.

Faculty Director: **Giulio De Leo**

ecohealthsolutions.stanford.edu/

HIGHLIGHTS

- DEHE leads Giulio De Leo and Susanne Sokolow were part of a team awarded a \$2.4 million National Science Foundation grant for their project, "A novel integration of fine scale ecological data, high-resolution precision mapping, and regional network

modeling to investigate environmental drivers of schistosomiasis dynamics."

- De Leo and Sokolow were part of a team awarded a Stanford Sustainability Initiative seed grant to draft a strategic plan to link Stanford's new school of sustainability with the School of Medicine as part of the university's Human and Planetary Health Accelerator. As part of the project, De Leo, Sokolow and DEHE affiliates Steve Luby and Katherine Burke launched a graduate-undergraduate course, "Human and Planetary Health: Investigating the socio-economic and ecological links between human health and Earth's natural ecosystems."
- De Leo was an invited panelist at an AAAS symposium session in which he gave a lecture on ecological solutions for the control of parasitic diseases of poverty.
- In October 2020, the World Economic Forum highlighted DEHE research showing the link between healthcare and deforestation. The analysis found that deforestation in an Indonesian national park declined 70 percent in the 10 years after an affordable health clinic opened in the area. The clinic, which accepts barter as payment and gives discounts to villages based on community-wide reductions in logging, could provide a blueprint for preserving the world's biodiverse carbon sinks while reversing poverty and poor health outcomes.

PUBLICATIONS

How to identify win-win interventions that benefit human health and conservation. *Nature Sustainability*

Three reasons why expanded use of natural enemy solutions may offer sustainable control of human infections. *People and Nature*

Improving rural health care reduces illegal logging and conserves carbon in a tropical forest. *Proceedings of the National Academy of Sciences*

Schistosome infection in Senegal is associated with different spatial extents of risk and ecological drivers for *S. haematobium* and *S. mansoni*. *PLOS Neglected Tropical Diseases*

Divergent ecological drivers and spatial extents of risk for *S. haematobium* and *S. mansoni* in a co-endemic landscape. *PLOS Neglected Tropical Diseases*

Land use impacts on parasitic infection: a cross-sectional epidemiological study on the role of irrigated agriculture in schistosome infection in a dammed landscape in West Africa. *Infectious Diseases of Poverty*

Agricultural innovations to reduce the health impacts of dams. *Sustainability*

Improving rural health care reduces illegal logging and conserves carbon in a tropical forest. *Proceedings of the National Academy of Sciences*

Visualization of schistosomiasis snail habitat using light unmanned aerial vehicles. *Geospatial Health*

Center on Food Security and the Environment (FSE)

FSE, a joint effort with the Freeman Spogli Institute for International Studies, addresses the challenges of feeding the world's growing population without depleting the planet's natural resources. FSE's team of interdisciplinary scholars addresses global hunger, poverty and environmental degradation by generating vital knowledge and policy-relevant

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solutions. Scholars with expertise in economics, political science, biology, civil and environmental engineering, law, earth science, medicine, anthropology, education and history are engaged in more than 20 research projects. They offer courses for graduate and undergraduate students interested in issues of hunger, rural development, global resource and environmental degradation, agricultural technology, climate impacts on food security, and agricultural trade and policy.

Faculty Director: **David Lobell**

Deputy Director: **Marshall Burke**

fse.fsi.stanford.edu/

HIGHLIGHTS

- The first five papers of the Blue Food Assessment, a project co-led by FSE and the Stanford Center for Ocean Solutions, were published this past September accompanied by a global launch event. The assessment is a global analysis on the diversity



of blue foods and the role they can play in transforming our food system. Ahead of the assessment, FSE Senior Fellow and Founding Director Rosamond Naylor wrote a related Op-ed for the Los Angeles Times.

- FSE scholars published a review in Science outlining how satellite-based techniques can enhance our ability to monitor global development but only when used in conjunction with ground-based techniques.
- Naylor led a study published in Nature highlighting the aquaculture industry's significant strides toward sustainability. The analysis, which was covered by The New York Times, notes that more effective oversight measures are needed to help ensure the economic viability of environmentally sound practices. Naylor and some of her coauthors shared observations from their analysis in a related seminar.

PUBLICATIONS

The effect of information about climate risk on property values. *Proceedings of the National Academy of Sciences*

Cleaner air has contributed one-fifth of US maize and soybean yield gains since 1999, *Environmental Research Letters*

Historical warming has increased U.S. crop insurance losses, *Environmental Research Letters*

Using satellite imagery to understand and promote sustainable development, *Science*

A million kernels of truth: Insights into scalable satellite maize yield mapping and yield gap analysis from an extensive ground

dataset in the US Corn Belt. *Remote Sensing of Environment*

Uniting remote sensing, crop modelling and economics for agricultural risk management. *Nature Reviews, Earth & Environment*

Changes in the drought sensitivity of US maize yields. *Nature Food*

The changing risk and burden of wildfire in the United States. *Proceedings of the National Academy of Sciences*

Global Freshwater Initiative (GFI)

GFI is an interdisciplinary research effort that studies the long-term viability of freshwater supplies for people and the environment. The program focuses on developing and water-scarce regions throughout the world, and considers threats from climate change, shifts in land use, increasing population and decaying infrastructure. In 2019-20, GFI focused on freshwater vulnerability in a variety of water-use sectors, with concentrated study on Jordan and India. The program has also continued to work on water resources in Colorado and eco-hydrologic problems in Canada and globally.

Faculty Director: **Steven Gorelick**

globalfreshwater.stanford.edu

HIGHLIGHTS

- GFI made major progress analyzing Jordan's freshwater resources projections under climate and demographic changes over the coming decades, evaluating the effectiveness

of policy interventions aimed at improving water sustainability. In addition to a publication in the *Proceedings of the National Academy of Sciences* showing that extraordinary measures must be taken to prevent a severe water crisis, the team held stakeholder workshops for representatives from civil society, government, industry and academia and produced a useful tool for water security analysis.

- Work in India, headed by graduate student Ju Young Lee and supervised by FUSE project co-PI Rosamond Naylor, resulted in an *Environmental Research Letters* publi-



cation that inspects the important sugar industry, its history, impacts and political economy. The study focused on the GFI field area in the state of Maharashtra, which includes Mumbai and Pune.

- GFI researchers were invited to give virtual lectures at institutions in China, Lebanon and Austria on

freshwater resources management topics in India, Jordan and globally.

- In his role as citationist at the Stockholm Water Prize ceremony, Gorelick discussed the accomplishments of 2021 prize winner Sandra Postel and 2020 prize winner John Cherry. The joint ceremony was held as part of *World Water Week*, with more than 13,000 participants from 168 countries.

PUBLICATIONS

Extracting Impervious Surface from Aerial Imagery Using Semi-Automatic Sampling and Spectral Stability. *Remote Sensing*

Distribution of small seasonal reservoirs in semi-arid regions and associated evaporative losses. *Environmental Research Communications*

Controlling arsenic mobilization during managed aquifer recharge: The role of sediment heterogeneity. *Environmental Science and Technology*

Insights on Expected Streamflow Response to Land-cover Restoration. *Journal of Hydrology*

Water-Food-Energy Challenges in India: Political Economy of the Sugar Industry. *Environmental Research Letters*

A coupled human-natural system analysis of freshwater security under climate and population change. *Proceedings of the National Academy of Sciences*

Increasing nutrient inputs risk an upsurge of global nitrous oxide emission from mangrove ecosystems. *One Earth*

Muskrats as a bellwether of a drying delta. *Communications Biology*

The Natural Capital Project (NatCap)

NatCap pioneers science, technology and partnerships that enable people and nature to thrive. This Stanford-led partnership works

through purposeful engagement and uses cutting-edge science and technology to drive a global transformation towards inclusive, green growth. NatCap operates as a global partnership of influential actors in academia, conservation, government, development banks, private investment and business. Its powerful network currently includes more than 50 research institutions and 200 implementing partners worldwide, allowing for direct engagements in over 60 countries and for the NatCap InVEST software platform to be used in more than 185 countries.



Faculty Director: **Gretchen Daily**

naturalcapitalproject.stanford.edu/

HIGHLIGHTS

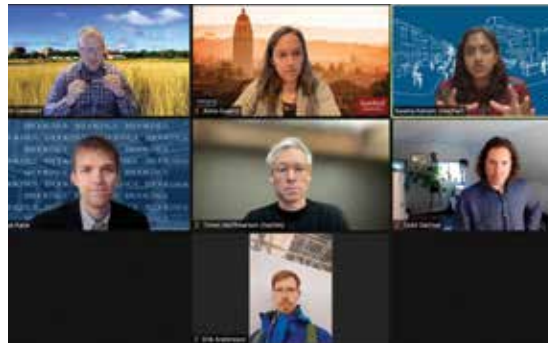
- In March, the UN Statistical Commission approved the Gross Ecosystem Product metric for global use. This new form of measurement— led by the Chinese Academy of Sciences and developed using NatCap science—was created to capture the

Research Centers & Programs

economic values of nature to society, drive investments in nature, and track progress. It is currently being deployed across China. NatCap has been invited to assist other countries with their adoption of the metric.

- NatCap [published](#) the science behind Urban InVEST, a software suite designed to understand the benefits nature provides to people in cities. The cities team published research on [physical health and nature](#) and authored a [World Bank policy brief on urban nature](#). Closer to home, the team published [a paper](#) exploring how seawalls can exacerbate regional flooding and damages from sea-level rise in the San Francisco Bay Area.
- As a way to maintain and grow their community of leaders in natural capital science and approaches in the midst of the pandemic, NatCap created the Natural Capital Conversations series. Over the course of 2021, NatCap hosted nine virtual webinars on topics including cultural ecosystem services, land-use planning, nature-based solutions and water and urban infrastructure. The series brought together more than 1,000 attendees from 74 countries and resulted in a successful new form of engagement for NatCap.
- NatCap conducted new science to inform policy development and innovative finance

with the governments of Belize, Costa Rica and Colombia. With multilaterals, they worked to operationalize new environmental and social safeguard standards and develop the Natural Capital Index (World Bank), developed new data technologies, capacity, and toolkits for climate resilience, worked towards



conducting ecosystem assessments for member countries (Inter-American Development Bank), and helped launched the Asian Development Bank's Natural Capital Lab.

PUBLICATIONS

Increasing decision relevance of ecosystem service science. *Nature Sustainability*

Mapping the benefits of nature in cities with the InVEST software. *Npj Urban Sustainability*

An ecosystem service perspective on urban nature, physical activity, and health. *Proceedings of the National Academy of Sciences*

Economic evaluation of sea-level rise adaptation strongly influenced by hydrodynamic feedbacks, *Proceedings of the National Academy of Sciences*

Joint strategic energy and river basin planning to reduce dam impacts on rivers in Myanmar. *Environmental Research Letters*

Harnessing new data technologies for nature-based solutions in assessing and managing risk in coastal zones. *International Journal of Disaster Risk Reduction*

Time and space catch up with restoration programs that ignore ecosystem service trade-offs. *Science Advances*

Advancing Sustainable Development and Protected Area Management with Social Media-Based Tourism Data. *Sustainability*

Eco-environmental impacts of dams in the Yangtze River Basin, China. *Science of The Total Environment*

A transition to sustainable ocean governance. *Nature Communications*

Program on Water, Health & Development (WHD)

WHD's research focuses on the role water plays in advancing global health and well-being. Program researchers pursue topics such as sustainable infrastructure, wastewater and stormwater management, poverty reduction, and health and hygiene education. While the COVID-19 pandemic has created challenges and limited most field-based research, it also has offered opportunities such as a new project examining how the coronavirus moves through the environment. This year, WHD has launched three newly funded projects focused on sub-Saharan Africa. One aims to enhance the poverty alleviation benefits of infrastructure investment. Another will analyze changes

in water resources and services in three countries over the next five years. The third will build capacity in the private and nonprofit sectors for in-depth problem diagnosis that leads to more sustainable solutions.

Faculty Director: Jenna Davis

water.stanford.edu

HIGHLIGHTS

- Over the course of 2021, WHD Deputy Director Rachel Cardone led the training of 20 professionals in Ghana, Uganda and Ethiopia in our new Systems Tools for Assessment and Response program, which provides the skills needed to facilitate robust



problem diagnosis and response development, using a systems-oriented approach. Graduates of the program, which was

developed with support from the Conrad N. Hilton Foundation, will support better strategy development, program design, measurement, evaluation and learning in the public, private and nonprofit sectors.

- In a new project funded by USAID, WHD affiliate Alexandria Boehm's group is collaborating with researchers at Tufts University to evaluate the efficacy of ash and sand as virus-removing hand washing agents. Ash and sand are widely used for handwashing in resource-constrained settings and have been recommended by the World Health Organization when soap and water are unavailable.
- The U.S. Department of Energy awarded a \$1.25 million grant to WHD affiliate Meagan Mauter and Ram Rajagopal, an associate professor of civil and environmental engineering, to develop a decision support tool for wastewater treatment facilities. The project aims to enhance treatment plants' profitability, while reducing their carbon footprint through increased biogas utilization and peak electricity consumption reductions.

- WHD affiliate William Tarpeh is leading a Stanford faculty team on a recently funded National Science Foundation project that aims to turn nitrogen wastewater pollutants into valuable products using techno-economic and life-cycle assessment for on-site wastewater valorization.

PUBLICATIONS

Joint inference of CFC lifetimes and banks suggests previously unidentified emissions. *Nature Communications*

A systematic evaluation of emerging wastewater nutrient removal and recovery technologies to inform practice and advance resource efficiency. *ACS ES&T Engineering*

Making wastewater obsolete: Selective separations to enable circular water treatment. *Environmental Science and Ecotechnology*

Standardizing data reporting in the research community to enhance the utility of open data for SARS-CoV-2 wastewater surveillance. *Environmental Science-Water Research and Technology*

A Day at the Beach: Enabling Coastal Water Quality Prediction with High-Frequency Sampling and Data-Driven Models. *Environmental Science & Technology*

Marginal energy intensity of water supply. *Energy & Environmental Science and Ecotechnology*

Desalination for a circular water economy. *Energy & Environmental Science and Ecotechnology*

Design, performance, and demand for a novel in-line chlorine doser to increase safe water access. *npj Clean Water*

Research Centers & Programs

Water in the West (WitW)

WitW integrates both science and policy research to develop innovative solutions to key water challenges in California and the American West. Researchers have revealed new insights into improving voluntary water markets, supporting effective implementation of California's Sustainable Groundwater Management Act (SGMA), and understanding groundwater recharge and quality.

Faculty Director: Barton "Buzz" Thompson

HIGHLIGHTS

- WitW welcomed Felicia Marcus as the William C. Landreth Visiting Fellow. Marcus is an attorney, consultant and member of the Water Policy Group who most recently served as chair of the California



State Water Resources Control Board. While at Stanford, Marcus has focused on water scarcity issues, urban water policy and nature-based climate solutions.

- Rosemary Knight, a professor of geophysics, Woods senior fellow and WitW faculty affiliate, is leading a project to integrate geophysical imaging of the subsurface to allow mapping of "fast paths" of sand and gravel that can move water underground to replenish groundwater systems. Critical to the state of California's water resources goals, this work is supported by SB 170, which allocated \$60 million for floodplain restoration projects.
- A study by Stanford Ph.D. graduate Kimberly Quesnell, M.S. graduate Saahil Agrawal and Newsha Ajami, director of Urban Water Policy at WitW, used Zillow and census data combined with machine learning to identify residential water consumption based on housing characteristics. The results, published in [*Environmental Research Letters*](#), could help cities better understand water use and design water-efficient communities.
- Researchers looked at 74 interorganizational agreements related to SGMA and the benefits of proactive management

of conflict. The findings were published in a report "[Dispute Resolution Clauses in Interorganizational Coordination Agreements: A Comparative Analysis](#)."

- In an [op-ed in Smart Water Magazine](#), Newsha Ajami outlined three transformative ideas for building a climate-resilient and equitable water sector as communities rebound from the pandemic, address



recent infrastructure failures and plan for the future. Another [op-ed in CalMatters](#) cowritten by Buzz Thompson, faculty director of WitW and a professor of law, argues that California's Department of Water Resources should enhance groundwater protection with changes to SGMA.

- Floodwaters could help recharge California's increasingly depleted groundwater systems, according to a study lead by Xiaogang He,

an assistant professor in civil and environmental engineering at the National University of Singapore who pursued the research as a postdoctoral fellow at WitW. The research develops a framework to calculate future floodwater volumes under climate change, and identifies areas where infrastructure investments in recharge could make a difference.

- Water rights in the West were historically on a first come first serve basis. It is estimated that by 2030 the entire water supply will be legally claimed in western U.S. watersheds, leaving little or nothing for new users. Meanwhile, population growth, urbanization, industrial development and climate-induced drought are stressing water supplies. In two studies, WitW postdoctoral scholar Philip Womble examined how changes to western U.S. water law that address impediments to voluntary water rights transfers could impact Colorado's water rights system. in California's San Joaquin Valley, providing a strategic blueprint for habitat restoration amid land use changes.

PUBLICATIONS

Diverse paradigms of residential development inform water use and drought-related conservation behavior. *Environmental Research Letters*

Dispute Resolution Clauses in Interorganizational Coordination Agreements: A Comparative Analysis. *Water in the West*

Climate-informed hydrologic modeling and policy typology to guide managed aquifer recharge. *Sciences Advances*

Mind the Gaps, The Case for Truly Comprehensive Sustainable Groundwater Management. *Water in the West*

Hot spots of opportunity for improved cropland nitrogen management across the United States. *Environmental Research Letters*

Mining the gap in long-term residential water and electricity conservation. *Environmental Research Letters*



Diverse paradigms of residential development inform water use and drought-related conservation behavior. *Environmental Research Letters*

Greenness Patterns During Severe Drought. *Environmental Research Letters*

Tools for Assessing Groundwater-Surface Water Connectivity Under the Sustainable Groundwater Management Act. *Water in the West*

Fellows & Research Staff

FELLOWS

Michelle Anderson, Senior Fellow, School of Law

Eric Appel, Center Fellow, by courtesy, Materials Science & Engineering, SOE

Nicole Ardoin, Senior Fellow, Graduate School of Education

Ines Azevedo, Senior Fellow, Energy Resources Engineering (SE3)

Jeremy Bailenson, Senior Fellow, Communication (H&S)

Bill Barnett, Senior Fellow, Graduate School of Business

Michele Barry, Senior Fellow, School of Medicine

Eran Bendavid, Senior Fellow, School of Medicine

Sarah Billington, Senior Fellow, Civil & Environmental Engineering (SOE)

Barbara Block, Senior Fellow, Hopkins Marine Station (H&S)

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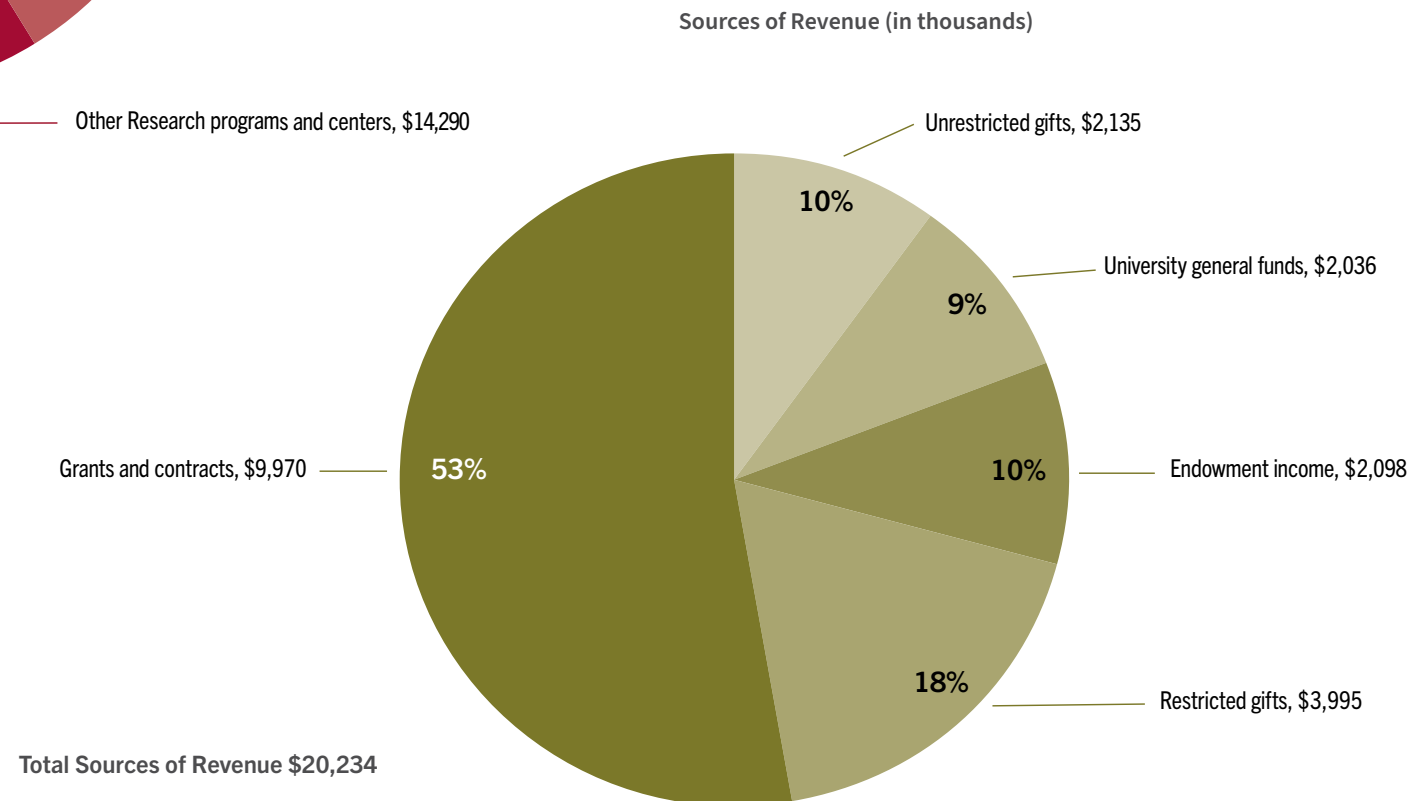
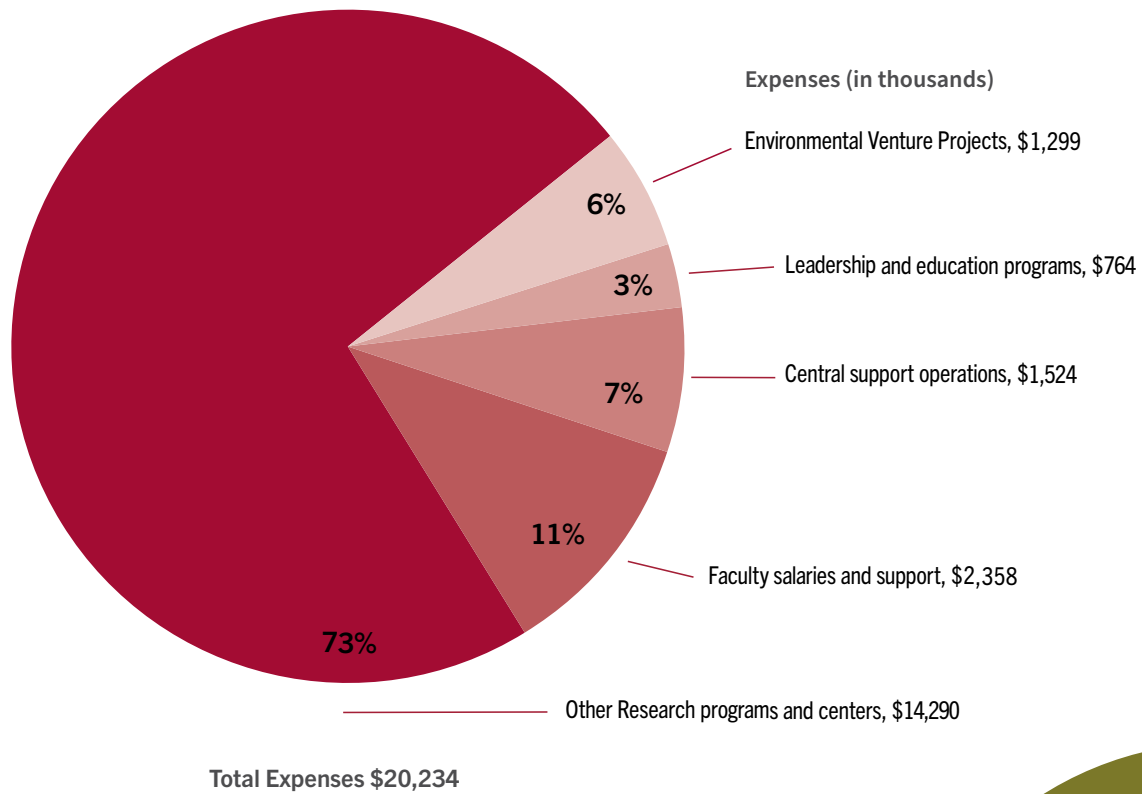
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FISCAL YEAR 2020–2021

Sources of revenue which support the Stanford Woods Institute for the Environment in fiscal year 2020–2021 amounted to \$21.8 million, of which 9 percent originated from university general funds, 10 percent from endowment income, 28 percent from gifts, and 53 percent from grants and contracts. Expenses during the fiscal year 2020–2021 amounted to \$21.8 million. Woods largest expenditure includes Environmental Venture Projects and other research programs and centers, totaling \$17.2 million, or 79 percent of the institute's annual budget.





FRONT Cover photo: The Penobscot River, ME, following a major river restoration and removal of the Veazie and Great Works Dams. Three years after these dam removals, American shad, alewives and other species returned in numbers not seen in decades, if not generations, according to coverage by the Portland Press Herald. The decision-making process for removal of the dams, installation of fish ladders and other restoration efforts served as a key inspiration for participants in a recent Woods Uncommon Dialogue that led to a landmark agreement and series of recommendations guiding the allocation of more than \$3 billion in federal funds for similar efforts. Read more about the dialogues on pages 10-11. **Photo credit: Gregory Rec/Portland Portland Press Herald via Getty Images.**



Stanford
WOODS
INSTITUTE for the
ENVIRONMENT

**Jerry Yang & Akiko Yamazaki Environment
& Energy Building—MC 4205**

473 Via Ortega
Stanford, CA 94305

Phone: 650.736.8668
Fax: 650.725.3402

Email: environment@stanford.edu