STANFORD ENVIRONMENTAL RESEARCH

2019 YEAR IN REVIEW

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ENVIRONMENT

This report covers research by faculty, students, postdoctoral scholars and research staff from across Stanford's seven schools.

DIRECTOR'S NOTE

For over a decade and a half, the Stanford Woods Institute for the Environment has been the university's front porch for climate science and solutions. Stanford's community of faculty, researchers, and students are world leaders, transcending the boundaries of traditional disciplines, departments, and schools to create the knowledge and solutions required to allow people and the planet to thrive. Their research produces fundamental insights and actionable guidance for scholars, decision-makers, and practitioners operating at local, regional, and global scales.

In 2019, that research has investigated the connections between deforestation and malaria, global warming and inequality, nature and mental health, and climate and conflict. It has led to innovation in how we fight wildfires, enable conservation, stop illegal fishing, recharge groundwater, measure ice-sheet change, and make decisions about how to prepare for a rapidly changing future. And it has advanced our understanding of environmental marketing, green growth, and the power and limits of natural climate solutions.

At Stanford, the Woods Institute serves as the interdisciplinary hub for leading scholars committed to working together to tackle unprecedented environmental challenges. As director, I'm honored, humbled, and inspired every day by the people, work, and potential of our institute. When one of the world's great universities and engines of innovation brings its passion, purpose, and creativity to bear on the problem of creating climate solutions, there is great reason for hope.

Chris Field

Chris Field

Perry L. McCarty Director

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RESEARCH AWARDS FOR ENVIRONMENTAL SOLUTIONS

For more than 15 years, the Stanford Woods Institute for the Environment has funded projects that bring together diverse groups of engineers, economists, doctors, geologists, lawyers, marine biologists and other experts to solve pressing environmental problems in new and innovative ways.

The Environmental Venture Projects (EVP) and Realizing Environmental Innovation Program (REIP) grants provide funding for out-of-the-box ideas that address challenges, such as long-neglected tropical diseases, groundwater overdraft, and wildfires, that are too complex to be solved by any one discipline alone. These interdisciplinary projects create compelling solutions, often focusing on low cost, high return innovations, that have the potential to be brought to scale.

Since the EVP program began in 2004 and the REIP program began in 2015, the Stanford Woods Institute has awarded more than $16 million in grants to 103 research teams representing all seven of Stanford's academic schools.

ENVIRONMENTAL VENTURE PROJECTS

EVP grants support high-risk research projects that focus on finding and creating real-world solutions by leveraging interdisciplinary collaboration. The projects selected for 2019 will each receive grants ranging from $49,998 to $200,000 over the next two years:

Combatting Air Pollution: China faces serious air quality problems likely to have profound population health effects. There is not yet agreement on clinically significant pollution exposure levels, relative importance of exposure durations or interactive effects of multiple pollutants. Rigorous evidence on the multidimensional pollution-mortality relationship is also needed. This project will build an unprecedented disaggregated dataset matching four years of hourly pollutant measurements with daily age-specific mortality rates in each of 278 cities in China. Using machine learning, the researchers will develop a data-driven empirical approach providing new evidence on these major research questions. They will also engage with key policymakers to disseminate findings. Grant Miller (Medicine), Lynn Hildemann (Civil and Environmental Engineering) and Hongbin Li (SIEPR)

Reimagining Wastewater: Centralized wastewater treatment exhibits a slow rate of adoption, is poorly suited for remote and resource-constrained communities, and requires considerable energy and greenhouse gas (GHG) emissions. This project seeks to create maximum value and minimal environmental impact from waste streams by advancing a novel biological-electrochemical treatment approach that can be adapted widely, requires less energy and emissions, and produces ammonium sulfate fertilizer and potable water. Looking at the molecular, process and systems scales, the researchers aim to accelerate its adoption by attracting interest from wastewater utilities and sanitation service providers. William Tarpeh (Chemical Engineering), Craig Criddle (Civil and Environmental Engineering) and David Lobell (Earth System Science)

Curbing Climate Change: As GHG concentrations rise, policymakers have explored negative-emissions technologies for carbon dioxide, but less so for methane. This project will test the feasibility of oxidizing methane from bulk air using zeolite, a crystalline material consisting primarily of aluminum, silicon and oxygen. Because of its porous molecular structure, relatively large surface area and ability to host copper and iron, it could act as a sponge to soak up methane. If successful at scale, the approach could restore methane concentrations to preindustrial levels and cut total radiative forcing by approximately one sixth. Robert Jackson (Earth System Science) and Edward Solomon (Chemistry)

Helping Species Thrive: To better understand the impacts of the world's oceans becoming warmer and less oxygenated, researchers will test and develop a new metabolic approach to map the aerobic habitable range for marine organisms, focusing initially on purple sea urchin and red abalone, species of high economic and ecologic importance in the California Current ecosystem. Once validated, scientists, environmental and fisheries managers, and others can use this approach to predict viable future ranges of individual species to guide management, monitoring and adaptive actions and paleontologists and geologists can use it to understand the causes of ancient mass extinctions. Erik Sperling (Geological Sciences), Fiorenza Micheli (Biology) and Chris Lowe (Biology)

Investigating Kidney Disease Links: To discover what causes chronic kidney disease of unknown etiology (CKDu), which afflicts up to 25% of adults in certain arid, low-land, monocrop farming regions, this project will investigate the environment of persons at-risk for CKDu in Sri Lanka. A preliminary study at a Sri Lankan hospital enabled non-invasive, clinical identification of probable CKDu. Using this case definition to enable recruitment and kidney biopsy protocols, the team will assess environmental exposures from water, soil, and rice to determine risk factors for CKDu, recruit participants and examine early-stage kidney biopsies for heavy metals and infectious pathogens. Shuchi Anand (Medicine), Vivek Bhalla (Medicine), Andrew Fire (Pathology and Genetics) and Neeraja Kambham (Pathology).

Capturing Glacier History: Improving projections of future sea level requires observing, modeling and understanding subsurface processes across spatial and temporal scales. Although observational data has been collected across much of Antarctica and Greenland, producing records of observations that span more than five decades, no cross-platform time-series of conditions have been produced. This project would digitize, calibrate and release film-based radar sounding data sets for the Greenland Ice Sheet held at the Technical University of Denmark. Dustin Schroeder (Geophysics) and Keith Winstein (Computer Science)

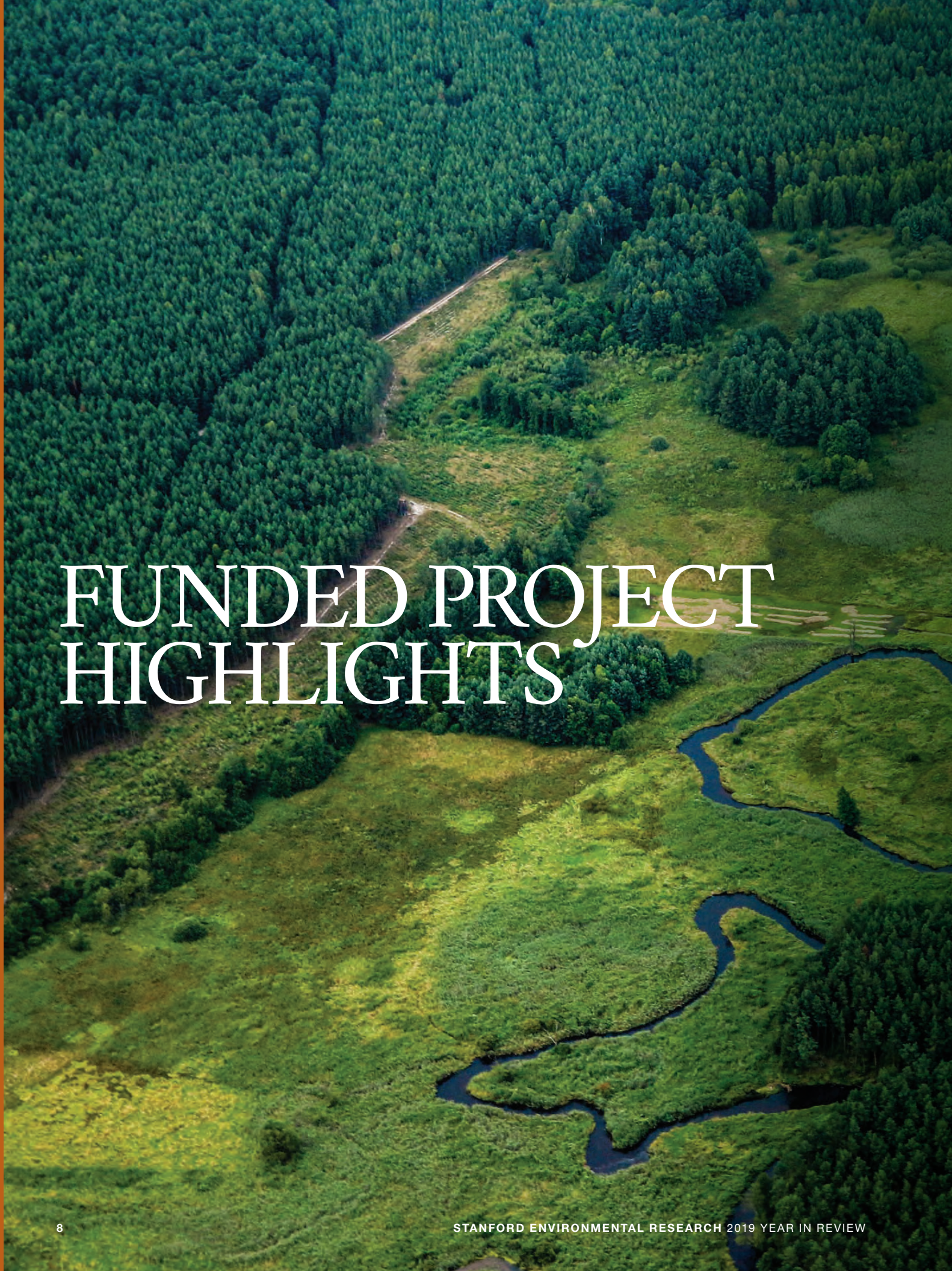
REALIZING ENVIRONMENTAL INNOVATION PROGRAM

REIP supports projects moving from the solution discovery phase to the validation phase of research and ultimately, to adoption by end users. The projects selected for 2019 will each receive grants ranging from $194,973 to $199,996 over the next two years:

Reducing Food Waste: In India, as high as 50% of fresh food is wasted, contributing to broad food insecurity and malnutrition. This project seeks to give Indian smallholder farmers access to food preservation technology. The team designed, built and tested affordable dryer and cooler prototypes that were scaled over a year of product development to meet farmers' specifications. The project will evaluate economic benefits and scaling potential with India-based partners through market surveys, pilot studies, business model development and recruitment of India-based entrepreneurial partners. Sally Benson (Energy Resources Engineering), Rosamond Naylor (Earth System Science), and Michael Machala (Energy Resources Engineering)

Ending Forced Labor in Fishing: Illegal, unreported, and unregulated fishing accounts for as much as one-third of seafood imports in major markets, and contributes to overfishing and labor abuse, with nearly 75% of workers reporting illegal overwork, underpay and debt bondage. This project will analyze existing practices and policies across the supply chain to determine how companies and policymakers could better design interventions to reduce forced labor in tuna fisheries. The researchers will use big data platforms to assess interventions at sea and examine how market mechanisms could incentivize greater transparency and traceability. Jim Leape (Center for Ocean Solutions) and David Cohen (Classics)

Recharging 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 snow melt moves into the subsurface and recharges the groundwater system. This project is developing a novel methodology for assessing site suitability for the approach, called flood-MAR (or ag-MAR). Using 3D images of sediment texture in the subsurface, researchers will rank various sites in terms of ability to rapidly move water to depth, and develop a flow and transport model that predicts water quality changes. This could provide a cost-effective and reliable approach for growers and improve groundwater sustainability. Rosemary Knight (Geophysics) and Kate Maher (Earth System Science)



FUNDED PROJECT HIGHLIGHTS

Feedback Between Deforestation and Malaria in the Amazon

MacDonald, A. J., & Mordecai, E. A. (2019). Amazon deforestation drives malaria transmission, and malaria burden reduces forest clearing. *Proceedings of the National Academy of Sciences*, 116(44), 22212–22218.

There is a direct relationship between deforestation and the transmission of malaria in the Amazon, according to a Stanford study that analyzed 13 years of geospatial data and malaria cases.

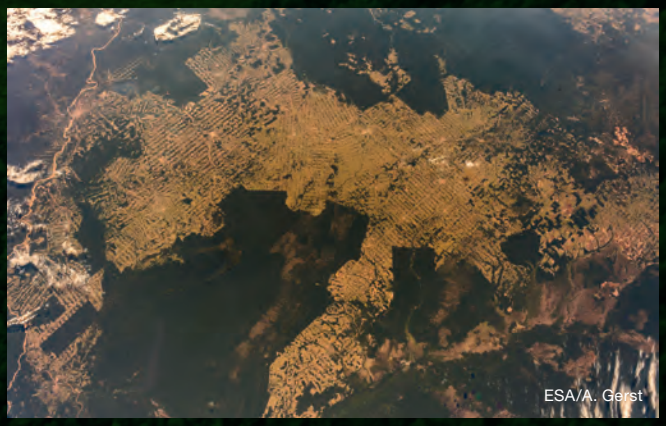
"Deforestation is a huge issue in the Brazilian Amazon because of the political and economic pressures pushing up against environmental health, biodiversity, social justice, and indigenous rights," explained senior author Erin Mordecai, assistant professor of Biology. "We found deforestation is not only an ecological disaster but also a major threat to human health."

Malaria is transmitted by mosquitos, which thrive in forest cleared and human altered landscapes. The researchers found that not only did areas with more deforestation see more malaria cases, but the rise in malaria was associated with a subsequent decrease in deforestation.

> For every square kilometer of forest lost we can expect about six new cases of malaria. At the same time, malaria affects the productivity and wellbeing of the populations settling the interior of the Amazon, where every malaria case leads to about 0.07 fewer square kilometers of forest being cleared.
>
> *— Erin Mordecai, assistant professor of Biology*

"Clearing forest can increase mosquitoes' breeding habitat on forest edges," said lead author Andy MacDonald, who was a postdoctoral scholar at Stanford and is now an assistant research professor at the University of California Santa Barbara. "It can also alter the microclimate, thereby changing the temperature that influences how fast the mosquito develops and how fast the parasite develops."

The study, published in the *Proceedings of the National Academy of Sciences* and funded in part by an EVP grant, highlights the unforeseen negative consequences for human populations of degrading the natural environment. "This is a clear case where deforestation is a lose-lose for the environment and public health, which is mostly borne by subsistence farmers and other settlers with few other economic opportunities," said Mordecai.


ESA/A. Gerst


Matt Zimmerman


Cesar David Martinez/Avaaz

Dangers of Pro-Environment Marketing for Cigarettes

Prashant Chaudhary

Epperson, A. E., Lambin, E. F., Henriksen, L., Baiocchi, M., Flora, J. A., & Prochaska, J. J. (2019). Natural American Spirit's pro-environment packaging and perceptions of reduced-harm cigarettes. *Preventive Medicine*, 126, 105782.

Epperson, A. E., Henriksen, L., Lambin, E. F., Flora, J. A., & Prochaska, J. J. (2019). Health beliefs of American Indian imagery on Natural American Spirit packs. *Tobacco Regulatory Science*, 5(4), 369–380.

Cigarettes – the leading preventable cause of death globally and most common form of litter – with pro-environment marketing on the packaging are perceived as less harmful to the environment and people's health, according to research by an interdisciplinary team at Stanford led by Judith Prochaska, associate professor of Medicine with the Stanford Prevention Research Center.

"Ecofriendly and natural food products are seen as safer for health," said lead author Anna Epperson, a postdoctoral fellow with the Stanford Prevention Research Center. "That couldn't be further from the truth when it comes to cigarettes."

Published in the journal *Preventive Medicine*, the survey compared two cigarette brands owned by the same company with the same health impacts: Pall Mall, which is marketed as a discount brand, and Natural American Spirit, which features a pro-environment marketing campaign highlighting "zero-waste-to-landfill" in manufacturing, tobacco leaves mimicking the recycling symbol, and the logo for the Programme for the Endorsement of Forest Certification, an organization promoting sustainable forest management.

Survey participants consistently ranked Natural American Spirit as less harmful to health and the environment. The results were strongest among current smokers, which could encourage switching brands instead of quitting.

A related study found the Natural American Spirit pack design featuring American Indian and thunderbird imagery creates a misperception that the brand is American Indian-owned or grown on tribal land and, thus, healthier. Both studies were funded by an EVP grant.

The researchers suggest regulations to prohibit using the word "natural" or pro-environment messaging in tobacco marketing and mandating plain packaging for cigarettes.

> "People need to be made aware of the risk of being manipulated by big brands that appeal to the environmental values of consumers to sell them products that are bad for their health."
>
> *— Eric Lambin, the George and Setsuko Ishiyama Provostial Professor in Earth System Science*

Groundwater Recharge with Recycled Water

Bradshaw, J. L., Osorio, M., Schmitt, T. G., & Luthy, R. G. (2019). System modeling, optimization, and analysis of recycled water and dynamic storm water deliveries to spreading basins for urban groundwater recharge. *Water Resources Research*, 55(3), 2446–2463.

Increasing groundwater recharge is critical to addressing the challenge of water scarcity and ensuring a sustainable water future. Using recycled water, instead of only storm water, to recharge aquifers can help address groundwater depletion, increase use of local water resources, and possibly increase groundwater quality. Yet, uncertainty about costs and integration with water infrastructure has resulted in limited adoption of recycled water in managed aquifer recharge (MAR).

Using a systems approach, Stanford researchers looked at MAR systems that send storm water and recycled water to spreading basins (ponds with high percolation rates) and created a model that can inform water planners about the costs, water volume, and energy trade-offs of these different multisupply spreading basin system designs. The study, funded in part by an REIP grant and published in *Water Resources Research*, used a case study in Los Angeles, California to show how the model works in the real world.

> In the 20th century we pumped more groundwater than was being replaced, particularly in the agricultural areas. Those days are over. The Sustainable Groundwater Management Act of 2014 requires that we manage our aquifers sustainably.
>
> *— Richard Luthy, the Silas H. Palmer Professor of Civil and Environmental Engineering*

The researchers' approach identified designs 5% to 20% more cost effective compared to conventional designs largely due to the greater use of water recycling facilities.

According to the authors "As cities continue to pursue more resilient water resource systems, efficiently designed multisupply spreading basin systems can offer cities cost-effective opportunities to recharge groundwater using local water supplies."


CADWR/Kelly M. Grow


CADWR/John Chacon


CADWR/John Chacon

Preventing Wildfires

Yu, A. C., Lopez Hernandez, H., Kim, A. H., Stapleton, L. M., Brand, R. J., Mellor, E. T., Bauer, C. P., McCurdy, G. D., Wolff, A. J., Chan, D., Criddle, C. S., Acosta, J. D., & Appel, E. A. (2019). Wildfire prevention through prophylactic treatment of high-risk landscapes using viscoelastic retardant fluids. *Proceedings of the National Academy of Sciences*, 116(42), 20820–20827.

A century of fire suppression coupled with a changing climate has intensified the destructive power of wildfires costing lives and billions in damages. Human activities near roads and utility infrastructure are responsible for sparking 85% of wildfires in the United States. Researchers at Stanford have now developed a preventive treatment that could be applied to these areas and greatly reduce the incidence and severity of wildfires.

Applied preventatively to ignition-prone areas, an environmentally benign gel-like fluid coupled with common wildland fire retardant, as outlined in a study funded in part by an REIP grant and published in the *Proceedings of the National Academy of Sciences*, can prevent fires throughout the peak fire season, even after rain and weather would wash away conventional fire retardants. By stopping fires from starting, such treatments increase effectiveness and save money.

"This has the potential to make wildland firefighting much more proactive, rather than reactive. What we do now is monitor wildfire-prone areas and wait with bated breath for fires to start, then rush to put them out," said senior author Eric Appel, assistant professor of Materials Science and Engineering.

USFS/Stuart Palley

The researchers worked with the California Department of Forestry and Fire Protection (CalFire) to test the treatment on grass and chamise, finding complete fire protection was retained even after half an inch of rainfall. Working with the California Department of Transportation and CalFire, the researchers are now testing the material on high-risk roadside areas.

The material, which is nontoxic and approved by the California Environmental Protection Agency, is currently undergoing certification by the U.S. Forest Service and is available now in large scale quantities.

> We hope these new materials can open the door to identifying and treating high-risk areas to protect people's lives and livelihoods.
>
> *— Eric Appel, assistant professor of Materials Science and Engineering*

USFS/Peter Buschmann

RESEARCH HIGHLIGHTS

Pete Veilleux, East Bay Wilds Nursery

Cultural Burning and Fire Management

Marks-Block, T., Lake, F. K., & Curran, L. M. (2019). Effects of understory fire management treatments on California Hazelnut, an ecocultural resource of the Karuk and Yurok Indians in the Pacific Northwest. *Forest Ecology and Management*, 450.

Incorporating traditional techniques into current fire suppression practices could help revitalize American Indian cultures, economies and livelihoods, while continuing to reduce wildfire risks. Traditional baby baskets of Northern California's Yurok and Karuk tribes are valuable in part because the hazelnut shrub stems used to make them are found only in forest understory areas experiencing a type of controlled burn once practiced by the tribes but which has been suppressed for more than a century.

A Stanford-led study with the U.S. Forest Service in collaboration with the Yurok and Karuk tribes replicates these fire treatments that involve cutting and burning hazelnut shrub stems. The approach increased the production of high-quality stems needed to make culturally significant items up to 10-fold.

"Burning connects many tribal members to an ancestral practice that they know has immense ecological and social benefit especially in the aftermath of industrial timber activity and ongoing economic austerity," said lead author Tony Marks-Block, a Ph.D. candidate working with Lisa Curran, the Roger and Cynthia Lang Professor in Environmental Anthropology.

Repeated prescribed burns reduce fuel for wildfires, thus reducing their intensity and size. The study, published in *Forest Ecology and Management*, could inform plans to incorporate the cultural burning practices into forest management, which could ease food insecurity among American Indian communities in the region by killing acorn-eating pests and promoting deer populations.

"Now that science has quantified and documented the effectiveness of these practices, fire managers and scientists have the information they need to collaborate with tribes to implement them on a large scale," said Curran.

> We must have fire in order to continue the traditions of our people. There is such a thing as good fire.
>
> *— Margo Robbins, director of the Yurok Cultural Fire Management Council who advised the researchers.*

Tony Marks-Block

Frank K. Lake US Forest Service/Karuk Tribe

Mapping Ecosystem Services

Chaplin-Kramer, R., Sharp, R. P., Weil, C., Bennett, E. M., Pascual, U., Arkema, K. K., Brauman, K. A., Bryant, B. P., Guerry, A. D., Haddad, N. M., Hamann, M., Hamel, P., Johnson, J. A., Mandle, L., Pereira, H. M., Polasky, S., Ruckelshaus, M., Shaw, M. R., Silver, J. M., … Daily, G. C. (2019). Global modeling of nature's contributions to people. *Science, 366*(6462), 255–258.

An interactive global map developed by Stanford researchers incorporates local-level analyses of nature's contributions to people and emphasizes nature's declining ability to protect people from water pollution, coastal storms and under-pollinated crops with up to 5 billion people at higher risk of reduced ecosystem services by 2050.

Nature supports people in a myriad of ways such as bees pollinating crops or wetlands removing chemicals from farm runoff. The study, published in the journal *Science*, could inform policy decisions with models showing areas to target for high-impact investments in natural ecosystems.

"Thanks to rapid recent technological improvements, we're now able to map these local contributions from nature in a detailed, accessible way at a global scale," said Becky Chaplin-Kramer, lead scientist at Stanford's Natural Capital Project and lead author on the study.

Using open-source software developed by the Natural Capital Project, the researchers modeled how water quality regulation, coastal hazard protection and crop pollination might change in the future.

They found that where people's needs for nature are greatest, nature's ability to meet those needs is declining. In all scenarios, developing countries, particularly in Africa and South Asia, are at a particular disadvantage.

"Our analyses suggest that the current environmental governance at local, regional and international levels is failing to encourage the most vulnerable regions to invest in ecosystems," said study co-author Unai Pascual, co-chair of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Values Assessment.

With an online viewer (viz.naturalcapitalproject.org/ipbes) that provides complex global data in an understandable way the researchers hope policymakers, development banks, and other global influencers will use the information to drive sustainable development and conservation.

> We hope that this work will advance the integration of nature's contributions to people into decision making and further galvanize global action.
>
> *— Becky Chaplin-Kramer, lead scientist at Stanford's Natural Capital Project*

Green Growth That Works

Mandle, L., Ouyang, Z. (Zhiyun), Salzman, J., & Daily, G. C. (2019). *Green growth that works: natural capital policy and finance mechanisms around the world*. Island Press.

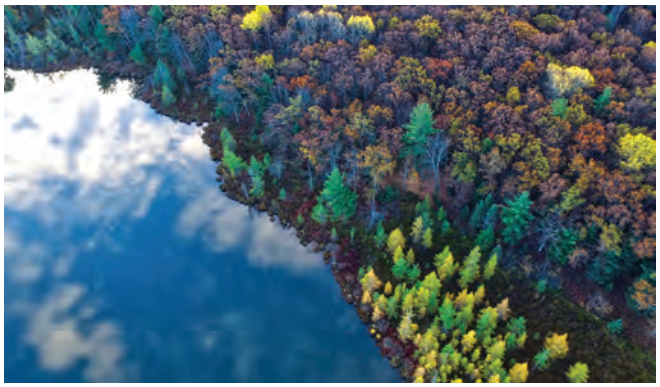
While rapid economic development has benefited human well-being by lifting millions out of poverty, raising the standards of living and increasing life expectancies, it has also taken a toll on natural capital, such as forests, coastal marshes, and fertile soils. To address the question of how to continue to improve the human condition without destroying nature, scholars at the Natural Capital Project suggest inclusive green growth—the efficient use of natural resources.

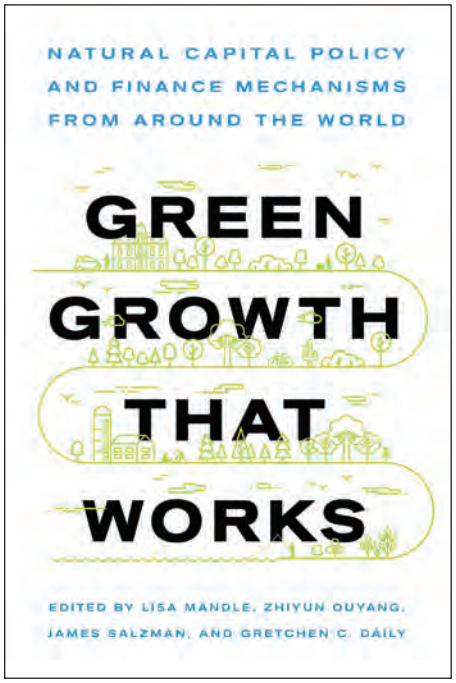
In the book *Green Growth That Works: Natural Capital Policy and Finance Mechanisms Around the World*, researchers explain that inclusive green growth minimizes pollution and strengthens communities against natural disasters while reducing poverty through improved access to health, education, and services.

> This book offers success stories from around the world and is designed to equip leaders to implement a green growth approach in their own community or region. It distills key lessons from the rapid advances in science, technology, policy and finance over the past two decades.
>
> *— Lisa Mandle, lead scientist at Stanford's Natural Capital Project*

The authors focus on mechanisms to restore and conserve ecosystems such as government subsidies, water funds, and voluntary conservation. Co-edited by Zhiyun Ouyang, James Edwin Salzman, and Gretchen Daily, the Bing Professor in Environmental Science and faculty director of the Stanford Natural Capital Project, the book serves as the first practical guide bridging pragmatic finance and policy tools to make investment in natural capital attractive and commonplace.

In October, Daily, Mandle, and Natural Capital Project Managing Director Mary Ruckelshaus discussed *Green Growth That Works* at a briefing for congressional staff on Capitol Hill and a panel at the National Press Club in Washington, D.C. focusing on successful examples of practical tools for conserving natural capital, nature-based solutions in cities, and the equity dimensions of green growth.





Island Press

New DNA Approach Empowers Conservation

Natesh, M., Taylor, R. W., Truelove, N. K., Hadly, E. A., Palumbi, S. R., Petrov, D. A., & Ramakrishnan, U. (2019). Empowering conservation practice with efficient and economical genotyping from poor quality samples. *Methods in Ecology and Evolution*, 10(6), 853–859.

For endangered species, DNA samples can reveal information on inbreeding, population history, and threats from habitat loss and the illegal wildlife trade, which can help guide conservationists on species recovery. But collecting samples from rare animals can be exceedingly expensive, challenging, and slow. To address this, researchers at Stanford and the National Centre for Biological Sciences at India's Tata Institute of Fundamental Research have developed an approach for extracting genetic information quickly and cheaply from degraded samples, such as hair and commercial food products.

> It's CSI meets conservation biology.
>
> *— Dmitri Petrov, the Michelle and Kevin Douglas Professor in the School of Humanities and Sciences*

The researchers focused on endangered wild tigers in India and overfished Caribbean queen conchs, examining tiger feces, shed hair, and saliva, as well as fried conch fritters from U.S. restaurants, samples too degraded for conventional genetic analysis.

"Our goal was to find extremely different species that had strong conservation needs, and show how this approach could be used generally," said co-author Stephen Palumbi, the Jane and Marshall Steele Jr. Professor of Marine Biology.

The sequencing approach, published in *Methods in Ecology and Evolution*, amplifies and reads small bits of DNA with unique differences simultaneously across many stretches of DNA in the same test tubes, thus minimizing the total amount of DNA needed. The procedure was made specific to tiger and conch DNA, allowing researchers to use samples contaminated with bacteria or other species DNA.

"We are working to expand the method so that it can identify other species and other characteristics, such as diet and pathogens," said co-author Elizabeth Hadly, the Paul S. and Billie Achilles Professor in Environmental Biology.

The new approach's effectiveness, speed and affordability represents a critical advance for wildlife monitoring, field-ready testing, and the use of science in policy decisions.

Tom Lee

Ending Illegal Fishing

Brett, A. (2019). *Ending Illegal Fishing: Data Policy and the Port State Measures Agreement*. www.weforum.org

Illegal, unreported and unregulated (IUU) fishing is a $23.5 billion problem that poses a serious threat to economies, the environment, and security, undermines legal fishing operations, and is associated with human trafficking, smuggling, and environmental degradation. In a working paper for the World Economic Forum, Stanford researchers examined how countries can share fisheries data in real time under the UN Port State Measures Agreement (PSMA) in order to achieve Sustainable Development Goal 14 (SDG 14), which entails ending IUU fishing by 2020.

"This work is all about making fisheries more sustainable, marine ecosystems more resilient, and coastal nation economies healthier," said Annie Brett, André Hoffmann Fellow at the Stanford Center for Ocean Solutions and World Economic Forum Center for the 4th Industrial Revolution.

The PSMA aims to deny culpable fishing vessels from using ports and landing catches, preventing them from reaching national and international markets. Using tuna fisheries case studies and consulting with fisheries experts, Brett found cross-jurisdictional cooperation; data platforms and exchange mechanisms; and resources and funding were critical for PSMA success.

> An essential piece of PSMA efficacy centers around countries sharing their near real-time data with one another, in order to ensure that IUU vessels are first identified and then quickly prevented from offloading their fish in ports.
>
> *— Annie Brett, André Hoffmann Fellow at the Stanford Center for Ocean Solutions and World Economic Forum Center for the 4th Industrial Revolution*

The study found existing pathways for data exchange, such as Regional Fisheries Management Organization. Further, coupling regional cooperation with national action plans to ensure interagency communication and cooperation could increase success. Implementing standardized data collection aligned with PSMA requirements could also increase efficiency and ensure regulation. On funding, the team suggests regional coordination of resources may be critical in ensuring investments are effective.

The study provides a pathway to implement the PSMA with a focus on effective data sharing to help end IUU by 2020.

The TerraMar Project

U.S. Navy/Kwabena Akuamoah-Boateng

Lead Found in Turmeric in South Asia

Forsyth, J. E., Nurunnahar, S., Islam, S. S., Baker, M., Yeasmin, D., Islam, M. S., Rahman, M., Fendorf, S., Ardoin, N. M., Winch, P. J., & Luby, S. P. (2019). Turmeric means "yellow" in Bengali: Lead chromate pigments added to turmeric threaten public health across Bangladesh. *Environmental Research*, 179.

Forsyth, J. E., Weaver, K. L., Maher, K., Islam, M. S., Raqib, R., Rahman, M., Fendorf, S., & Luby, S. P. (2019). Sources of blood lead exposure in rural Bangladesh. *Environmental Science & Technology*, 53(19), 11429–11436.

To give turmeric, a spice used widely throughout South Asia, its signature yellow color, some spice processors in Bangladesh use an industrial lead chromate pigment that is responsible for elevating blood lead levels, according to two studies by Stanford researchers published in *Environmental Research* and *Environmental Science and Technology.* Considered unsafe in any quantity and banned from food products, lead is a potent neurotoxin that increases the risk of heart and brain disease and harms brain development.

> People are unknowingly consuming something that could cause major health issues. We know adulterated turmeric is a source of lead exposure, and we have to do something about it.
>
> *— Jenna Forsyth, a postdoctoral scholar at the Stanford Woods Institute for the Environment*

The researchers interviewed farmers and spice processors in Bangladesh who discussed a massive flood in the 1980s that left turmeric crops dull in color. With high demand for bright yellow curry, turmeric processors added lead chromate, commonly used to color toys and furniture. Because the ratio of isotopes of lead vary by origin, the researchers were able to match lead isotopes found in people's blood to those from lead chromate-adulterated turmeric.

"Unlike other metals, there is no safe consumption limit for lead, it's a neurotoxin in its totality," said senior author Stephen Luby, professor of Medicine and director of research at Stanford's Center for Innovation in Global Health.

With funding from an EVP grant, Forsyth, Luby and co-author Scott Fendorf, the Terry Huffington Professor of Earth System Science, have worked for years in rural Bangladesh assessing lead exposure. They are now focused on shifting consumers from contaminated turmeric and reducing incentives for the practice. They recommend changes in drying technologies for turmeric processing and advise importing countries to screen turmeric with X-ray devices that can detect lead.

Global Inequality and Climate Change

Diffenbaugh, N. S., & Burke, M. (2019). Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences*, 116(20), 9808–9813.

Global warming has increased economic inequality between countries over the past several decades, according to a study published in the *Proceedings of the National Academy of Sciences*. Stanford researchers found the gap between the economic output of the world's richest and poorest countries is 25% larger than it would have been without global warming.

"Our results show that most of the poorest countries on Earth are considerably poorer than they would have been without global warming. At the same time, the majority of rich countries are richer than they would have been," said lead author Noah Diffenbaugh, the Kara J Foundation Professor in Earth System Science.

The study explains that warming increases growth in cool countries like Norway, while decreasing growth in warmer countries like Nigeria through impacts to agricultural output, labor productivity, human health and other factors. From 1961 to 2010, the wealth per person in the world's poorest countries was decreased by 17 to 30% due to global warming. Poor countries have the double disadvantage of not benefitting equally from widespread energy access and being harmed by the climate change associated with fossil fuels for energy production in wealthy countries.

"For most countries, whether global warming has helped or hurt economic growth is pretty certain," said co-author Marshall Burke, assistant professor of Earth System Science.

Economic output with and without global warming was determined using climate models to isolate how much each country has already warmed due to climate change and previous work by Burke estimating the effects of temperature on economic growth.

> "Our study makes the first accounting of exactly how much each country has been impacted economically by global warming, relative to its historical greenhouse gas contributions."
>
> *— Noah Diffenbaugh, the Kara J Foundation Professor in Earth System Science and Kimmelman Family Senior Fellow at the Stanford Woods Institute for the Environment*

Influence of Climate on Risk of Armed Conflict

Mach, K. J., Kraan, C. M., Adger, W. N., Buhaug, H., Burke, M., Fearon, J. D., Field, C. B., Hendrix, C. S., Maystadt, J. F., O'Loughlin, J., Roessler, P., Scheffran, J., Schultz, K. A., & von Uexkull, N. (2019). Climate as a risk factor for armed conflict. *Nature*. 571, 193–197.

Intensifying climate change will increase the risk of violent armed conflict within countries substantially, finds a study published in the journal *Nature*. Synthesizing views across experts, the study estimates climate has influenced between 3% and 20% of armed conflict risk over the last century and that the influence will likely increase dramatically.

"Appreciating the role of climate change and its security impacts is important not only for understanding the social costs of our continuing heat-trapping emissions, but for prioritizing responses, which could include aid and cooperation," said Katharine Mach, the study's lead author who served as director of the Stanford Environment Assessment Facility and is now an associate professor at the University of Miami.

Climate change-driven extreme weather and disasters can damage economies, lower farming and livestock production and intensify inequality among social groups, which may increase risks of violence.

The analysis involved interviews and debates among experts in political science, environmental science, and other fields who have come to different conclusions on climate's influence on conflict in the past. While the experts agree that climate has affected organized armed conflict in recent decades, they make clear that other factors, such as low socioeconomic development, have a much heavier impact on conflict within countries.

Adaptation strategies, such as crop insurance, can increase food security, diversify economic opportunities, and reduce potential climate–conflict linkages. Peacekeeping, conflict mediation and post-conflict aid operations could incorporate climate into their risk reduction strategies.


Oxfam East Africa

> Knowing whether environmental or climatic changes are important for explaining conflict has implications for what we can do to reduce the likelihood of future conflict, as well as for how to make well-informed decisions about how aggressively we should mitigate future climate change.
>
> *— Marshall Burke, assistant professor of Earth System Science*


Oxfam


Aurélie Marrier d'Unienville / IFRC

Climate and Soil Arsenic Threaten Rice Yields

Muehe, E. M., Wang, T., Kerl, C. F., Planer-Friedrich, B., & Fendorf, S. (2019). Rice production threatened by coupled stresses of climate and soil arsenic. *Nature Communications*, 10, 4985.

Future climate conditions and arsenic-induced soil stress could decline rice yields by about 40% by 2100, finds a Stanford-led study published in *Nature Communications*. This would jeopardize a critical food source and impact 2 billion people dependent on the crop.

The researchers ran experiments exploring rice production in future climate conditions using greenhouses to control for temperature, carbon dioxide and soil arsenic levels, which will likely go up with increased irrigation using arsenic-contaminated water. They simulated a possible 5 degree Celsius temperature increase and doubling of carbon dioxide, based on projections by the Intergovernmental Panel on Climate Change.

Rice, which is grown in flooded paddies, is especially prone to arsenic uptake. Due to higher temperatures combined with flooded conditions, researchers found that changes to soil processes will increase arsenic in rice by twice as much. Arsenic exposure can lead to skin lesions, cancers, and death. Further, arsenic inhibits nutrient absorption and decreases plant growth leading to lower crop yields.

Kurt Hickman/Stanford

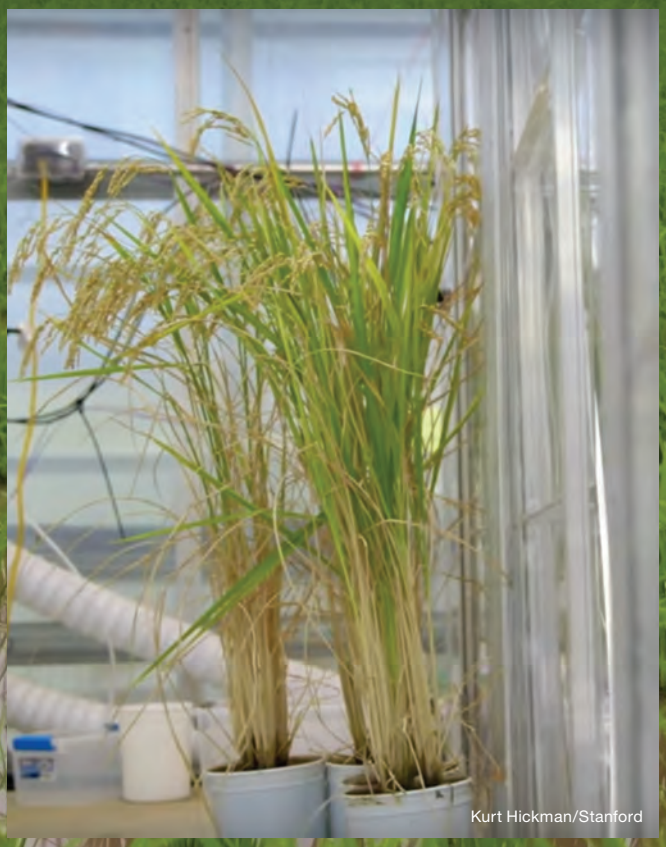
Rice is also a low-allergen food often introduced early to infants. "Because infants are a lot smaller than we are, if they eat rice, that means that they take up more arsenic relative to their body weight," said lead author E. Marie Muehe, a former postdoctoral scholar at Stanford and now at the University of Tübingen.

Going forward, the researchers plan to use remote sensing to locate contaminated rice paddies and model future global rice yields and arsenic contamination.

> I just didn't expect the magnitude of impact on rice yield we observed. What I missed was how much the soil biogeochemistry would respond to increased temperature, how that would amplify plant-available arsenic, and then – coupled with the temperature stress – how that would really impact the plant.
>
> *— Scott Fendorf, the Terry Huffington Professor in Earth System Science.*

Kurt Hickman/Stanford

Kurt Hickman/Stanford



Kurt Hickman/Stanford

Recovering Nitrogen from Wastewater

Liu, M. J., Neo, B. S., & Tarpeh, W. A. (2020). Building an operational framework for selective nitrogen recovery via electrochemical stripping. *Water Research*, 169.

Roughly 1% of the world's energy supply is used to create nitrogen-based fertilizers and the nitrogen is then consumed and excreted by humans into wastewater. Currently, methods for treating wastewater only remove rather than recover this nitrogen. Researchers at Stanford are looking at ways to recover nitrogen from wastewater to be used as fertilizer or other products, which in the future may help offset the cost of treatment and increase resource-efficiency.

"We are engineering new chemical processes to extract valuable chemicals like sulfur, nitrogen and phosphorous from water, and then use these to create valuable products like fertilizers, disinfectants and more. It's recycling, but for water," said Will Tarpeh, assistant professor of Chemical Engineering and senior author on a study, published in the journal *Water Research*, that provides an operational framework for nitrogen recovery via electrochemical stripping (ECS).

After a proof-of-concept study showed that ECS, a process that selectively extracts ammonium sulfate from wastewater, recovered nitrogen at 93%, researchers took the concept further and found ECS performed well over a range of realistic ambient temperatures, three gas permeable membranes, and three orders of magnitude of influent, untreated wastewater, concentrations. These results show that ECS can be applied to a wide range of operating conditions.

According to the authors, "as a result of this work, electrochemical stripping continues to mature from concept to practice and provides lessons for developing other resource recovery technologies."

Natural Climate Solutions and Decarbonization

Anderson, C. M., DeFries, R. S., Litterman, R., Matson, P. A., Nepstad, D. C., Pacala, S., Schlesinger, W. H., Rebecca Shaw, M., Smith, P., Weber, C., & Field, C. B. (2019). Natural climate solutions are not enough. *Science*, 363(6430), 933–934.

Natural climate solutions, such as reducing deforestation, restoring wetlands, and changing farming practices, can create carbon sinks that take carbon out of the atmosphere or prevent certain emissions that contribute to global warming. Enthusiasm for these approaches is growing but scientists warn that these natural solutions are only part of the answer and do not lessen the need for mitigation in the industrial and energy sectors.

In a perspective in the journal *Science*, researchers from Stanford and other institutions discussed how groups promoting natural solutions that underemphasize the urgency of moving away from fossil fuels risk sowing misunderstanding in the public conversation and delaying action on reducing emissions. While protecting carbon sinks, such as forests and wetlands, is vital to slowing climate change, it is only one strategy among many that should be combined with reductions in emissions, according to the researchers.

> The science has long been consistent that even if we maximize our use of natural climate solutions, there is still an emissions gap that requires decarbonizing energy and industry.
>
> — *Christa Anderson, research fellow at the World Wildlife Fund.*

"The world has clearly passed the point where we can avoid all of the damages from climate change, but every ton of carbon dioxide not emitted decreases future damages. With each passing week, stabilizing warming at well under 2 degrees Celsius, the goal of the 2015 Paris climate agreement, looks increasingly unlikely. But a path of ambitious mitigation can still keep the world in a zone where adaptation can help us cope effectively with the impacts of climate change," said Perry L. McCarty Director Chris Field, a co-author on the perspective.

The researchers stress that strategies for incorporating natural climate solutions and mitigation in the energy and industrial sectors should not be "either/or" but "yes, and."

Methane Removal and Atmospheric Restoration

Jackson, R. B., Solomon, E. I., Canadell, J. G., Cargnello, M., & Field, C. B. (2019). Methane removal and atmospheric restoration. *Nature Sustainability* 2(6), 436–438.

An approach for converting methane to carbon dioxide could make a big difference in the fight against climate change, according to a comment by Stanford researchers published in the journal *Nature Sustainability*.

> If perfected, this technology could return the atmosphere to pre-industrial concentrations of methane and other gases.
>
> — *Rob Jackson, the Michelle and Kevin Douglas Provostial Professor in Earth System Science*

Though less abundant, methane, which has reached atmospheric concentrations 2.5 times that of pre-industrial levels, is 84 times more potent in terms of warming the climate system over the first 20 years of its release compared with carbon dioxide. There are some sources of methane emissions that may be very difficult or expensive to eliminate, such as those from cattle.

"An alternative is to offset these emissions via methane removal, so there is no net effect on warming the atmosphere," said co-author Chris Field, the Perry L. McCarty Director of the Stanford Woods Institute for the Environment.

In contrast to carbon dioxide which would need hundreds of billions of tons removed from the atmosphere to limit warming, methane concentrations could be restored to pre-industrial levels by removing about 3.2 billion tons and converting it into an amount of carbon dioxide equivalent to a few months of global industrial emissions. The approach could potentially eliminate about one-sixth of all causes of global warming to date.

Capturing methane is difficult because its concentration is so low, but the authors argue that zeolites, a crystalline material that consists primarily of aluminum, silicon and oxygen, could act as a sponge to soak up methane. A zeolite array could capture methane which could then be heated to form and release carbon dioxide. This process could also be profitable with a price on carbon emissions or other policy options.

Blake Thornberry

Mapping Symbiotic Relationships in Forests

Steidinger, B. S., Crowther, T. W., Liang, J., Van Nuland, M. E., Werner, G. D. A., Reich, P. B., Nabuurs, G., de-Miguel, S., Zhou, M., Picard, N., Herault, B., Zhao, X., Zhang, C., Routh, D., Peay, K. G., Abegg, M., Adou Yao, C. Y., Alberti, G., Almeyda Zambrano, A., … Zo-Bi, I. C. (2019). Climatic controls of decomposition drive the global biogeography of forest-tree symbioses. In *Nature*, 569(7756), 404–408.

Using data from 1.1 million forest plots and 28,000 tree species, researchers uncovered patterns of the symbiotic relationships between plant roots, fungi and bacteria. In a study in *Nature*, researchers mapped where the most abundant symbiotic relationships exchanging nutrients for carbon on the forest floor will flourish. These maps are freely available and useful for better understanding the world's forests and the impacts of climate change.

Working with a team of over 200 scientists, Stanford researchers used the map to predict that the biomass of tree species associated with a certain type of fungi found primarily in cooler regions may see a 10% reduction by 2070 if carbon emissions continue at their current rate. This loss could lead to more carbon in the atmosphere because these fungi increase the amount of carbon stored in soil.

"Our models predict massive changes to the symbiotic state of the world's forests – changes that could affect the kind of climate your grandchildren are going to live in," said lead author Brian Steidinger, a postdoctoral researcher at Stanford.

The team used the location of 31 million trees from the Global Forest Biodiversity Initiative database, which surveyed forests, woodlands and savannas from every ecosystem on Earth, information on the symbiotic fungi or bacteria associated with them, and a learning algorithm for how variables such as climate and soil chemistry influence the prevalence of each symbiosis. They found nitrogen-fixing bacteria are likely limited by soil acidity and temperature, whereas fungal symbioses are more influenced by variables affecting decomposition rates such as moisture.

The scientists named their new biological rule after Sir David Read, a pioneer of symbiosis research.

> These are incredibly strong global patterns, as striking as other fundamental global biodiversity patterns out there.
>
> — *Kabir Peay, associate professor of Biology*

Nature and Mental Health

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., … Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances* (Vol. 5, Issue 7).

Researchers are proposing a way to bring the mental health benefits of nature to city dwellers through incorporating nature in urban design. An international team led by Stanford and the University of Washington created a model to help city planners, developers, and others anticipate the mental health impacts of conserving nature. Examples might be neighborhood parks, trees planted along streets or better transportation access to natural areas.

"In all of human history, people have never been so disconnected from nature, and we're becoming ever more so. Alongside this trend, there is a significant increase in some types of mental health disorders worldwide. Our work focuses on the connections between these trends and what we can do about them," said Gretchen Daily, senior author of the *Science Advances* study and faculty director of the Stanford Natural Capital Project.

Roughly two-thirds of the world's population will live in cities by 2050. Urban dwellers often face more time indoors, on screens and removed from nature, which can exacerbate mental health issues. Experts agree that contact with nature can reduce risk for some mental illnesses as well as improve memory, life management, and attention. The authors hope this model will be useful in considering the potential mental health impacts of increasing or decreasing access to nature, especially in disadvantaged communities.

> "If the evidence shows that nature contact helps to buffer against negative impacts from other environmental predictors of health, then access to these landscapes can be considered a matter of environmental justice. We hope this framework will contribute to the discussion."
>
> — *Greg Bratman, assistant professor at the University of Washington*

Impacts of High-Tide Flooding

Hino, M., Belanger, S. T., Field, C. B., Davies, A. R., & Mach, K. J. (2019). High-tide flooding disrupts local economic activity. *Science Advances*, 5(2).

As the climate changes and sea levels rise, coastal communities like Annapolis, Maryland are threatened not only by extreme weather events, but by increasingly frequent high-tide flooding which occurs when ocean waters rise above the levels that coastal infrastructure was designed for.

These more frequent floods typically last just a few hours but according to a study published in the journal *Science Advances*, they are taking a financial toll on local businesses. Researchers found that downtown Annapolis suffered a loss of 3,000 visits in 2017 due to high-tide flooding, which equates to between $86,000 and $172,000 in lost revenue.

Once relatively rare, high-tide flooding days have increased about 60% in 20 years. In the early 1960s, Annapolis had about four high-tide flooding days a year. In 2017, it had 63 days.

Researchers used parking meters, satellite imagery, interviews and other data to determine how would-be customers were dissuaded from visiting during flood hours at a popular business region known as City Dock.

Matt Rath/Chesapeake Bay Program

Matt Rath/Chesapeake Bay Program

"So often we think of climate change and sea level rise as these huge ideas happening at a global scale, but high-tide flooding is one way to experience these changes in your daily life just trying to get to your restaurant reservation," said Miyuki Hino, the study's lead author who completed her Ph.D. in Stanford's Emmett Interdisciplinary Program in Environment and Resources and is now an assistant professor at the University of North Carolina.

In 2017, the loss to City Dock businesses due to flooding was less than 2% of annual visitors, but if sea level increases by 12 inches, visits would be reduced by about 24%, which could mean hundreds of thousands in lost revenue. Possible adaptations include changes in business or customer behavior, and changes in infrastructure, such as new drainage pumps to reduce flooding. The U.S. Global Change Research Program Climate Science Special Report has sea level rise projections relative to the year 2000 ranging between 0.5 and 1.2 feet by 2050.

> "What we're finding is something many local leaders in coastal cities already know: the waters are rising up and surging into daily life. So are the costs. Understanding the impacts for people today – at large and small scale – is an essential starting point for making smart adjustments to the risks."
>
> — *Katharine Mach, associate professor at the University of Miami*

Amy McGovern

Evaluating Natural Hazard Decision Aids

Wong-Parodi, G., & Small, M. J. (2019). A decision-centered method to evaluate natural hazards decision aids by interdisciplinary research teams. *Risk Analysis*.

Though preparing in advance for natural hazards, such as floods and hurricanes, can save lives, preserve property, and help avoid or lessen impacts, many people do not ready themselves for the risks. To address this, researchers, often interdisciplinary teams of experts are creating decision aids to inform people about risks, management options and issues concerning the natural hazards they may encounter. Yet due to a lack of resources and clear guidance, these decision aids are largely unevaluated and their effectiveness is not deeply known.

In a perspective in the journal *Risk Analysis*, Gabrielle Wong-Parodi, assistant professor of Earth System Science and Mitchell Small, professor at Carnegie Mellon University, created a method for evaluating these decision aids and how they impact users.

"We present a decision-centered method for evaluating the impact of hazard decision aids on decisionmaker preferences and choice during the design and development phase, drawing from the social and behavioral sciences and a value of information framework to inform the content, complexity, format, and overall evaluation of the decision aid," wrote the authors.

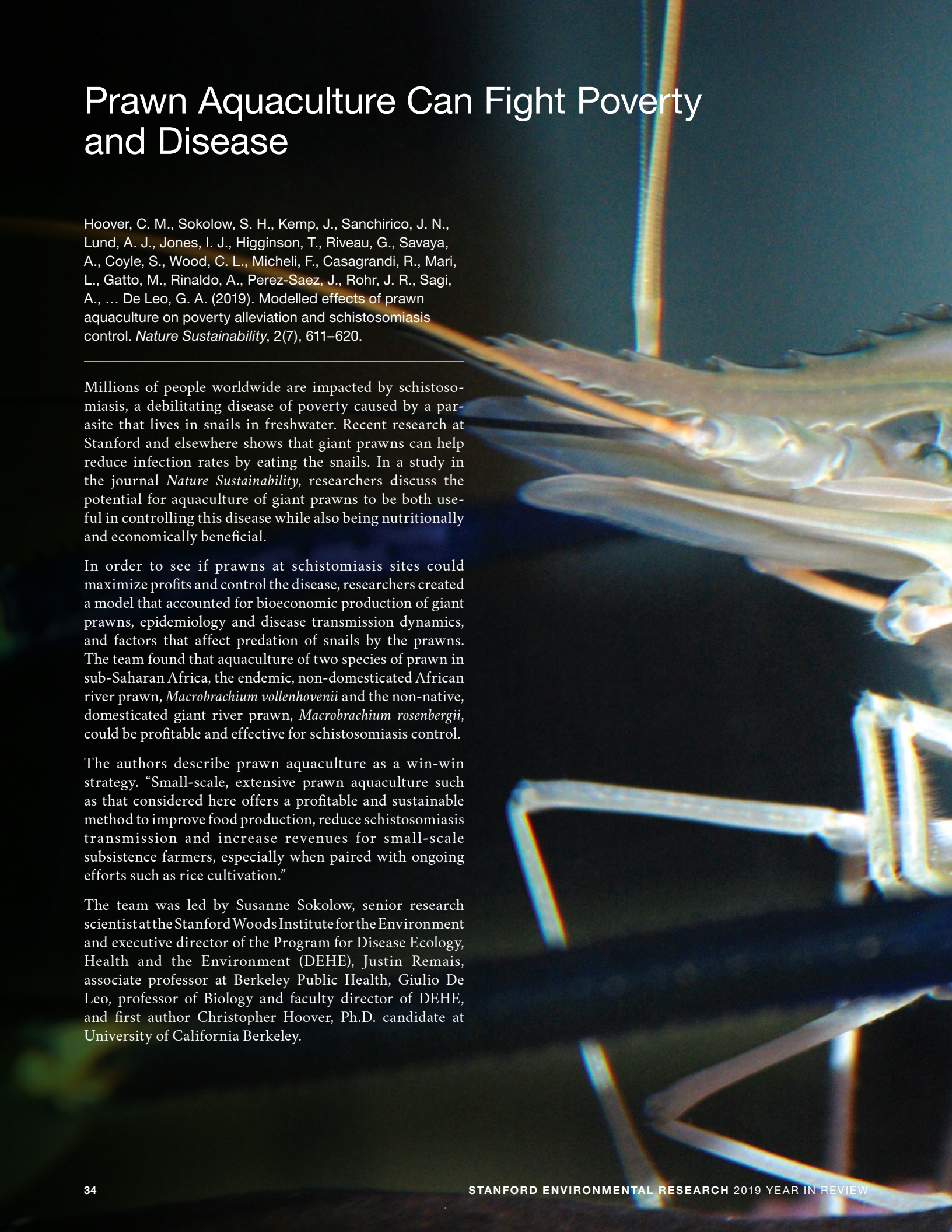
The method involves understanding the added value of information in the decision aid and assessing the extent to which it is usable. Applicable to many different types of hazards and disasters, the method can help interdisciplinary teams creating these aids to better understand whether they will work to actually impact people's decisions, such as building sea walls or buying flood insurance, to prepare for coastal flooding from sea-level rise.

USCG/Petty Officer 3rd Class Jaclyn Young


US Army National Guard/1Lt. Zachary West, 100th MPAD


USCG/Petty Officer 2nd Class Kyle Niemi

Prawn Aquaculture Can Fight Poverty and Disease



Hoover, C. M., Sokolow, S. H., Kemp, J., Sanchirico, J. N., Lund, A. J., Jones, I. J., Higginson, T., Riveau, G., Savaya, A., Coyle, S., Wood, C. L., Micheli, F., Casagrandi, R., Mari, L., Gatto, M., Rinaldo, A., Perez-Saez, J., Rohr, J. R., Sagi, A., … De Leo, G. A. (2019). Modelled effects of prawn aquaculture on poverty alleviation and schistosomiasis control. *Nature Sustainability*, 2(7), 611–620.

Millions of people worldwide are impacted by schistosomiasis, a debilitating disease of poverty caused by a parasite that lives in snails in freshwater. Recent research at Stanford and elsewhere shows that giant prawns can help reduce infection rates by eating the snails. In a study in the journal *Nature Sustainability*, researchers discuss the potential for aquaculture of giant prawns to be both useful in controlling this disease while also being nutritionally and economically beneficial.

In order to see if prawns at schistomiasis sites could maximize profits and control the disease, researchers created a model that accounted for bioeconomic production of giant prawns, epidemiology and disease transmission dynamics, and factors that affect predation of snails by the prawns. The team found that aquaculture of two species of prawn in sub-Saharan Africa, the endemic, non-domesticated African river prawn, *Macrobrachium vollenhovenii* and the non-native, domesticated giant river prawn, *Macrobrachium rosenbergii*, could be profitable and effective for schistosomiasis control.

The authors describe prawn aquaculture as a win-win strategy. "Small-scale, extensive prawn aquaculture such as that considered here offers a profitable and sustainable method to improve food production, reduce schistosomiasis transmission and increase revenues for small-scale subsistence farmers, especially when paired with ongoing efforts such as rice cultivation."

The team was led by Susanne Sokolow, senior research scientist at the Stanford Woods Institute for the Environment and executive director of the Program for Disease Ecology, Health and the Environment (DEHE), Justin Remais, associate professor at Berkeley Public Health, Giulio De Leo, professor of Biology and faculty director of DEHE, and first author Christopher Hoover, Ph.D. candidate at University of California Berkeley.

Ethan Trewhitt

Takeaway

Syrist

Jarek Tuszyński

Extending Records of Antarctic Change

Schroeder, D. M., Dowdeswell, J. A., Siegert, M. J., Bingham, R. G., Chu, W., MacKie, E. J., Siegfried, M. R., Vega, K. I., Emmons, J. R., & Winstein, K. (2019). Multidecadal observations of the Antarctic ice sheet from restored analog radar records. *Proceedings of the National Academy of Sciences*, 116(38), 18867–18873.

Using a system for digitizing Hollywood films, researchers have extended records of Antarctic ice melt by decades with radar data that was captured on 35mm film in the 1960s and 70s. By comparing the ice-penetrating radar records with modern data, the study, published in the P*roceedings of the National Academy of Sciences,* found that Thwaites Glacier in West Antarctica is melting faster than expected, between 10 and 33% from 1978 to 2009. The result means the ice shelf of a glacier the size of Florida could collapse sooner than previously thought which has implications for sea-level rise predictions and planning for coastal communities.

The film data comes from airborne radar surveys which allow scientists to see terrain beneath the ice and layers showing climate history. In collaboration with the Scott Polar Research Institute at the University of Cambridge, the team digitized about 250,000 flight miles of Antarctic radar data which they released to the public through Stanford Libraries. The organization of the data was aided by Stanford computer scientists.

"The opportunity to use big data analysis and computer vision techniques to make a contribution to glaciology – that's a rare and thrilling thing for us," said co-author Keith Winstein, assistant professor of Computer Science.

With this historical dataset, the researchers hope to enable other scientists to study changes in ice thickness and conditions in Antarctica over time.

Schroeder and Winstein have an EVP grant to digitize more archival data of the Greenland ice sheet at the Technical University of Denmark.

> By being able to look back 40 to 50 years at subsurface conditions rather than just the 10 to 20 years provided by modern data, scientists can better understand what has happened in the past and make more accurate projections about the future.
>
> — *Dustin Schroeder, assistant professor of Geophysics*

Dustin Schroeder


Dustin Schroeder

Greenland's Impact on the Atlantic Jet Stream

White, R. H., Hilgenbrink, C., & Sheshadri, A. (2019). The importance of Greenland in setting the northern preferred position of the North Atlantic Eddy-Driven Jet. *Geophysical Research Letters*, 46(23), 14126–14134.

The topography of Greenland is responsible for the northernmost position of the Atlantic jet stream, according to a Stanford study that builds on previous research showing the jet stream hovers around three preferred latitudes. The jet stream over the North Atlantic is a fast-flowing air current that has significant impact on weather and climate over Europe. By changing the environment and landscapes in an atmospheric general circulation model, such as adding or removing mountains, the researchers found that while two of the positions for the jet stream were stable regardless of what changes were made, the northernmost position was controlled by just one thing: Greenland. The northern position disappeared when Greenland was flattened in the models.

"I was actually kind of disappointed because I thought that it was going to be something a bit more complicated than that – something involving a bit of complex flow dynamics – but it's just Greenland," said Aditi Sheshadri, an assistant professor of Earth System Science.

The researchers found that the northern peak in Greenland is what is known as a tip jet, essentially a flow that impacts the edge of Greenland resulting in a downstream acceleration of flow. Thus, the jet stream's northernmost position is not a set regime but instead a consequence of Greenland and its mountains. The results of the study, published in *Geophysical Research Letters*, are important to factor in to climate models, particularly because Greenland is slowly melting in response to climate change.

> We really care about the Atlantic jet stream because people live on both sides of it. Understanding something about how much it's changing and why it looks like it does is really important to human lives, and potentially sub-seasonal prediction.
>
> — *Aditi Sheshadri, assistant professor of Earth System Science*


Stig Nygaard

Collapse of Mexico's Jumbo Squid Fishery

Frawley, T. H., Briscoe, D. K., Daniel, P. C., Britten, G. L., Crowder, L. B., Robinson, C. J., & Gilly, W. F. (2019). Impacts of a shift to a warm-water regime in the Gulf of California on jumbo squid (Dosidicus gigas). *ICES Journal of Marine Science*.

In 2008, the Gulf of California jumbo squid fishery was the fourth largest in Mexico and employed over 1,500 fishing vessels. By 2015, it had completely collapsed. The mystery of what caused the decline of Mexico's once lucrative jumbo squid fishery was finally solved when Stanford researchers uncovered a perfect storm of warming waters, shifting weather patterns, changing ocean conditions, and reduced food contributing to the collapse. The finding spells trouble for marine ecosystems and fishery-dependent economies in the Gulf of California and elsewhere.

"What is happening with the jumbo squid is indicative of larger changes impacting marine organisms and ecosystems across the northeast Pacific," said the study's lead author, Timothy Frawley, a Ph.D. candidate working with William Gilly, professor of Biology. "In many respects these squid, with their unique and adaptive survival strategies, function as sentinels of environmental change."

In the study published in the *ICES Journal of Marine Science*, the researchers compiled official fisheries records, oceanographic data, and biological measurements of over 1,000 individual squid to identify changes in ocean habitat that coincided with reductions in squid size, life span and fisheries productivity. They found currents and circulation patterns have shifted over the past decade resulting in increasingly warmer tropical waters across the region instead of the cooler, nutrient-rich waters ideal for the jumbo squid and its prey. Thus, the squid have shorter life spans and smaller growth, making them more difficult to catch and less profitable for the fishing industry.

> These results show that our traditional understanding of the dynamics underlying fisheries, their management and sustainability are all at risk when environmental change is rapid and persistent.
>
> — *Larry Crowder, the Edward Ricketts Provostial Professor of Marine Ecology and Conservation at Stanford's Hopkins Marine Station*


Sheraz Sadiq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Heartbeat of a Blue Whale Recorded

Goldbogen, J. A., Cade, D. E., Calambokidis, J., Czapanskiy, M. F., Fahlbusch, J., Friedlaender, A. S., Gough, W. T., Kahane-Rapport, S. R., Savoca, M. S., Ponganis, K. V., & Ponganis, P. J. (2019). Extreme bradycardia and tachycardia in the world's largest animal. *Proceedings of the National Academy of Sciences*, 116(50), 25329-25332.

For the first time, researchers have recorded a blue whale's heart rate in the wild. The measurement suggests that the heart of Earth's largest species is operating at extremes, which may be limiting its size.

> I honestly thought it was a long shot because we had to get so many things right: finding a blue whale, getting the tag in just the right location on the whale, good contact with the whale's skin and, of course, making sure the tag is working and recording data.
>
> — *Jeremy Goldbogen, assistant professor of Biology*

Using a suction cupped sensor device secured to the whale's left flipper, researchers monitored the whale's heart rate through electrodes embedded in two of the suction feet.

"We're always looking to push the boundaries of how we can learn about these animals," said coauthor David Cade, a graduate of lead author Jeremy Goldbogen's lab who placed the tag on the whale.

The study, published in the *Proceedings of the National Academy of Sciences*, showed as the whale dove, its heart rate slowed to an average minimum of about four to eight beats per minute, going as surprisingly low as two beats per minute. When the whale lunged and consumed prey, the heart rate increased about 2.5 times the minimum before decreasing. As the whale returned to the surface, the heart rate increased with its highest heart rates of 25 to 37 beats per minute occurring at the surface where the whale breathed and restored its oxygen levels.

"Animals that are operating at physiological extremes can help us understand biological limits to size," said Goldbogen. "They may also be particularly susceptible to changes in their environment that could affect their food supply. Therefore, these studies may have important implications for the conservation and management of endangered species like blue whales."

Gregory Smith

Modeling Land Subsidence

Smith, R., & Knight, R. (2019). Modeling land subsidence using InSAR and airborne electromagnetic data. *Water Resources Research*, 55(4), 2801–2819.

In California's Central Valley, the state's most productive agricultural region, overpumping of groundwater has depleted aquifers and caused subsidence, the sinking of land, permanently depleting groundwater storage capacity and damaging infrastructure. Using remote sensing data, Stanford researchers have developed a way to map precisely where and how to use groundwater recharge, the flooding of fields, to refill aquifers and curb subsidence.

The study, published in *Water Resources Research*, warns the ground at some sites will sink by 13 feet or more over 20 years, and even if overpumping is addressed, sinking may continue due to a delayed effect from past overdrafts.

"There is a time delay in the system," said senior author Rosemary Knight, the George L. Harrington Professor in the School of Earth Sciences. "The only way we can stop it is to be strategic about what we do with our available recharge water."

Due to recent drought years, Central Valley farmers have relied more on groundwater. "It's a perfect storm of an extensive agricultural industry combined with low precipitation, warm temperatures, the need for pumping groundwater and an abundance of clay that is prone to subsidence," said Knight. When pumped dry, clays can compact and release arsenic into water supplies.

Knowing where water is going when flooding fields for recharge is critical for success, but getting data from drilling contractors can be expensive and limited. The study, which used electromagnetic signals from a helicopter to analyze the structure of sand and clay layers as well as data from satellite images to measure subsidence, offers a more cost-effective approach and includes a method for adapting existing algorithms to integrate the two datasets into one model.

> "If we are proactively managing then we can prevent unrecoverable storage loss."
>
> — *Ryan Smith, professor at Missouri University of Science and Technology*

USGS/Justin Brandt

USGS/Justin Brandt

CADWR/Florence Low

Predicting Fire in South Asian Peatlands

Dadap, N. C., Cobb, A. R., Hoyt, A. M., Harvey, C. F., & Konings, A. G. (2019). Satellite soil moisture observations predict burned area in Southeast Asian peatlands. *Environmental Research Letters*, 14(9), 094014.

In Southeast Asia, peatland fires create thick deadly smoke and release huge amounts of carbon into the atmosphere once stored in soil and plants. Haze from peatland fires was linked to 100,000 premature deaths in Indonesia, Malaysia and Singapore in 2015.

"Although they only cover 3% of the world's land area, peatlands are estimated to contain 21% of the world's soil carbon," said Nathan Dadap, Ph.D. candidate in Earth System Science and lead author on a study that uses satellite measurements to correlate soil moisture with fire vulnerability in peatlands.

Many thought satellite monitoring of soil moisture in swampy tropical peatland was impossible because the ground can be obscured by vegetation and other factors. To address this, Stanford researchers developed an alternative algorithm and using data from NASA's Soil Moisture Active Passive (SMAP) mission, found that the conversion of tropical forests to palm oil and acacia plantations allowed for measurement of the soil moisture in this region. The study, published in *Environmental Research Letters,* showed drier soil up to 30 days before a fire correlated with a larger burned area. Thus, soil moisture can be a more direct predictor of fire risk than rainfall.


Nathan Dadap


Aulia Erlangga/CIFOR


Aulia Erlangga/CIFOR

"This clearly shows the potential to lead to improved fire predictions," said Alexandra Konings, assistant professor of Earth System Science and senior author of the study. "More research is needed, but it opens the door to a new way of figuring out long-term policies for managing peatland fire risk."

Predicting and better managing fires in peatlands is critical as they can become out of control and have devastating impacts to the environment, human health, and climate change.

> In the 2015 peat fires, nearly the same amount of carbon dioxide was released as India's total annual carbon emissions from fossil fuels.
>
> — *Nathan Dadap, Ph.D. candidate in Earth System Science*


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STANFORD ENVIRONMENT RESEARCH 2019

CITATIONS

CLIMATE

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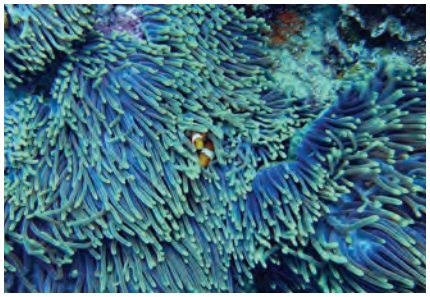

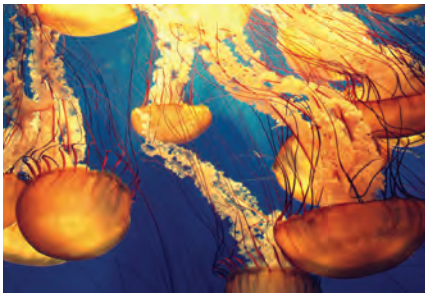

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