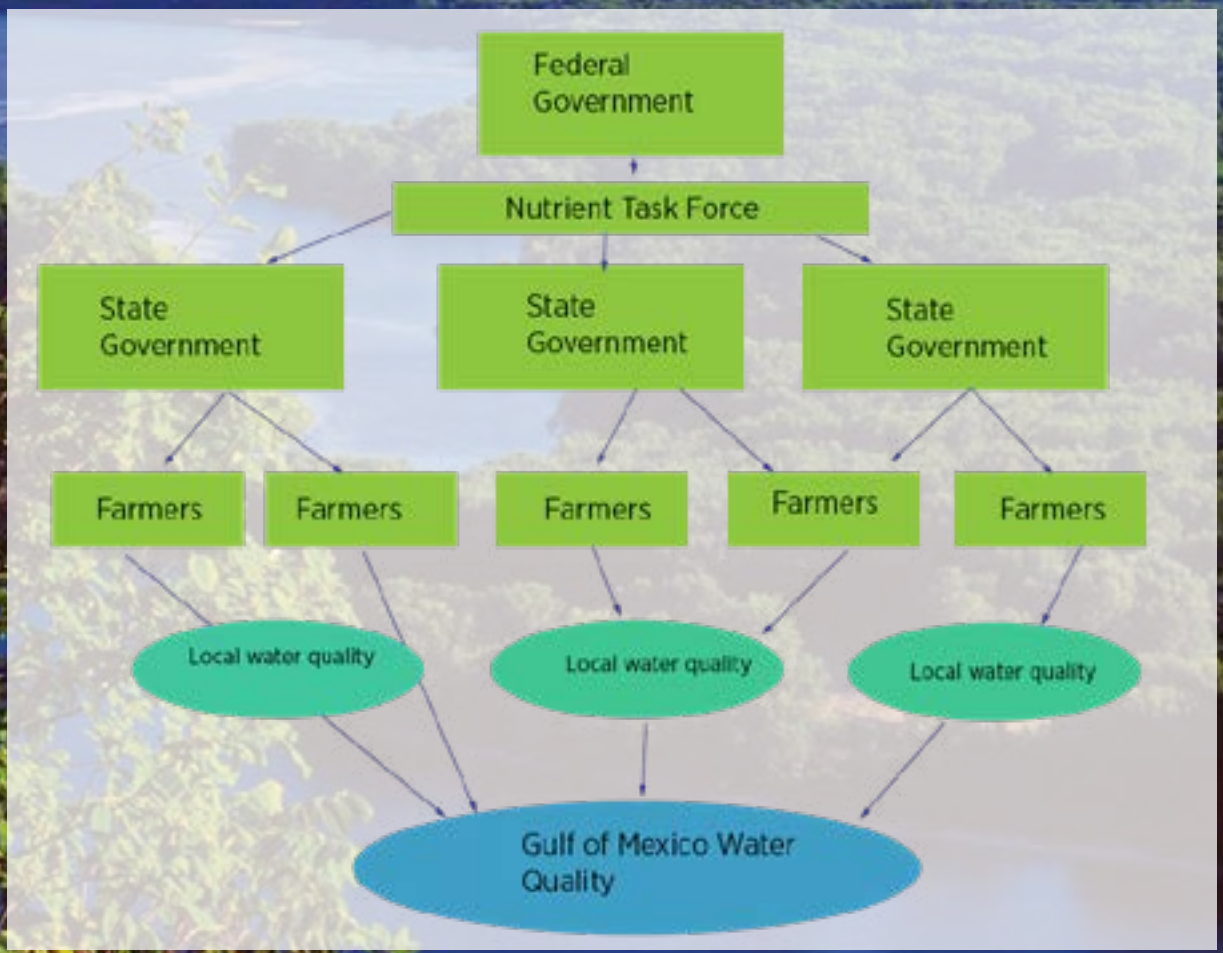
ESPPulse

A publication of the Michigan State University Environmental Science and Policy Program

SPRING 2018

The role of policy as an adaptive feedback for addressing reactive nitrogen issues in the Mississippi River Basin

An environmental policy paper by
Riva C.H. Denny and Kateri R. Salk
Michigan State University



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Photographs by MSU Photos

FROM THE DIRECTOR

After eight years as director of ESPP, it is now time for me to move onto a different role. This is my final letter as director, I would like to take this opportunity to reflect what I have learned and the changes that have taken place since I joined the program in 2010.

Overall, the past eight years have been a great experience, helping broadened my perspectives on my own research, on scientific research and education in general, and on the roles and responsibilities of scientitsts in society.

Being the ESPP director allowed me to interact with a large group of researchers in other disciplines, both at MSU and beyond. This greatly expanded my research portfolio. Since 2010, I have obtained 9 large interdisciplinary grants from NSF, USDA, EPA and NASA. Many of these wouldn't have been possible without the opportunities ESPP offered to interact with others.

During my tenure, our work together has lead to many achievements, including:

- Grew our graduate program,
- Tripled our student enrollment in the doctoral specialization,
- Turned the specialization to a dual major with about 20 departments and schools,
- Started a new graduate specialization in environmental modeling.

We have seen successes in enabling and promoting interdisciplinary environmental research collaboration at MSU through signature programs including ITBI, VISTAS, WaterCube and the Water Science Network, as well as a series of grant programs and events to connect researchers across disciplines.

ESPP has also lead to the integration of research and education through signature events including the ESPP Research Symposium, the Research Colloquia Series, the Distinguished Lecture Series, the Fate of Earth endowment and conferences.

This August, I will begin the next chapter in my career at Michigan State University. Starting with a sabbatical., I'm looking forward to working on my ongoing research projects and starting new ones.

I am excited to be returning to the roots of universities' fundamental land grant pillars of teaching, research and outreach. Warmest wishes to the upcoming Director of the Environmental Science and Policy Program, and to the ESPP community, of which I will continue to be a loyal and enthusiastic member.

All the best,

Jinhua Zhao, ESPP Director

ESPP Research Symposium 2017

Urban Environment Sustainable Solutions for the Future

The annual ESPP Fall Research Symposium, held on October 27, 2017, an opportunity for graduate and undergraduate students, as well as postdoctoral researchers, to present their research on a specific theme. The 2017 theme was Urban Environment: Sustainable Solutions for the Future.
This conference connected ideas and researchers from across campus to identify challenges and form appropriate solutions in urban environment. A holistic approach toward sustainability requires multiple perspectives, and this event intends to foster such interdisciplinary sharing. This symposium explored research performed across disciplines, among public stakeholders, and alongside policy makers to better prepare future leaders in addressing the state of the urban environment.

Plenary speakers included:
- Dr. Dan Costa, National Program Director in the U.S. Environmental Protection Agency's Air, Climate, and Energy Research Program
- The Honorable Bob Dixson, mayor of Greensburg, Kansas
- Dr. Shawn McElmurry, Wayne State University
- Dr. Harsha Ratnaweera, Professor and Head of Research at the Faculty of Sciences and Technology, Norwegian University of Life Sciences

Research Symposium Planning Committee for 2017 included:
- Hogeun Park (College of Agriculture and Natural Resources, ESPP);
- Teng Zhang (College of Social Science);
- Peyman Akbari (College of Veterinary Medicine),
- Meghna Chakraborty (College of Engineering)

Faculty advisors:
Dr. Jan Beecher (Institute of Public Utilities), Dr. Guo Chen (Geography, Environment and Spatial Sciences), Dr. Tim Gates, (Civil and Environmental Engineering) Dr. Jack Harkema (Pathobiology)and Dr. M.G. Matt Syal (Planning, Design and Construction).

From left: Dr. Jinhua Zhao, Dr. Shawn McElmurry, Bob Dixson, Dr. Dan Costa, Dr. Harsha Ratnaweera

Research Colloquia Series 2017-2018

By Sierra Jankowski, ESPP Student Aide

ESPP Research Colloquia 2017-18 focuses on urbanization and sustainability, battles for Michigan's fish, social equality and environmental justice, and biotechnologies.

The Research Colloquia Series utilizes ESPP's unique network of expertise within and beyond MSU to address important and timely environmental issues that cross disciplinary boundaries. The ESPP's Research Colloquia Series is a forum for students, researchers, and visitors to engage in research discussions where an interdisciplinary perspective is critical.

In October, Panelists Dr. Dan Costa, US EPA; Dr. Harsha Ratnaweera, Norwegian University of Life Sciences; Bob Dixson, Mayor of Greensburg Kansas; and Dr. Shawn McElmurry, Wayne State University came together to discuss "Urbanization and Sustainability" with organization and moderation by Zachary Curtis, Engineering and ESPP.

Also in October, ESPP and Fisheries and Wildlife student Betsey Riley presented "The Battle for Michigan's Fish" using an innovative interviewing technique to quantify risk perception and inform outreach with Dr. Triezenberg (MSU Extension) and Dr. Chris Weeks (Fisheries and Wildlife).

November saw another panel discussion on "Social Inequality and Environment Justice" featuring Garret Ziegler (MSU Extension), Joe T. Darden (Geography), and Sharlissa Moore (James Madison College) and organized by Ran Duan (Media Information and ESPP).

A panel discussion took place in January 2018 on "Sustainable Food Systems in Devoloping Countries" featuring Karimbhai Maredia, Professor of Entomology, Michigan State University; Jennifer Hodbod, Assistant Professor, Community Sustainability, Michigan State University; and Jelili Adebiyi, PhD student in Community Sustainability and ESPP. This colloquium was organized and moderated by Christina Azodi, PhD student in Plant Biology and ESPP.

Also in January, Azodi presented on "Perceptions of Emerging Biotechnologies" with a panel discussion featuring Rob Last, Barnett Rosenberg Professor in the Departments of Biochemistry, Molecular Biology and Plant Biology; John Besley, Associate Professor in the Department of Advertising and Public Relations and the Ellis N Brandt Chair in Public Relations; and Joseph Hamm, Associate Professor in the School of Criminal Justice and Appointed Faculty of Environmental Science and Policy.

From left, Dr. Jennifer Hodbod, MSU; Dr. Karimbhai Maredia, MSU; Jelili Adebyi, MSU and Dr. Karen Garrett, University of Florida and organizer Christina Azodi, Plant Biology and ESPP

Fate of the Earth 2018

Thanks to the generous endowment of Barbara Sawyer Koch and Dr. Donald Koch, the Fate of the Earth annual symposium is charged with exploring the challenges and opportunities we face in enhancing human well-being while protecting the environment. In 2018, Fate of the Earth has expanded to more than just academic and scientific discussion into a wide-ranging event designed to appeal to participants of all ages and backgrounds who are determined to do their part to protect, enhance and preserve our enviornmental future.

Two plenary speakers have been selected to address the audience on the intersections of local and global environmental issues. In addition, the folk duo Magpie will inspire action through music and share their experiences of advocacy through art.

Finally, a series of workshops held throughout the day engaged children, families, students, homeowners, and activists of all ages to discover the roles they play in the Fate of the Earth.

Speakers include:

Dr. Bill Lynn

Bill Lynn is a research scientist in the George Perkins Marsh Institute at Clark University, and former Director of the Masters in Animals and Public Policy (MAPP) program at Tufts University. Schooled in ethics, geography, and political theory, his interdisciplinary approach examines why and how we ought to care for nature and society. Sustainability is more than preserving a global elite's lifestyle or ensuring humanity's mere survival in an era of rampant environmental change. It is rather about sustaining the well being of people, animals, and nature across the planet, now and into the distant future. Sustainability needs, therefore, to be both scientifically and ethically sound. Its facts and values need to be transparent and accountable to society, while its goals must serve the good of the entire community of life.

Christy George

Christy George has covered climate change and the environment for 20 years – for both radio and television. She's worked for PBS-TV's "History Detectives;" Marketplace Radio; Oregon Public Broadcasting, WGBH-TV; and the Boston Herald, and edits news for public radio reporters from Olympia, Washington to Salt Lake City, Utah.

She's won three Emmys, an Edward R. Murrow award, and a Gracie Allen award, and she shared in Marketplace's team Columbia-duPont Silver Baton. She was a 1991 John S. Knight Journalism Fellow at Stanford University and serves on the board of directors of the Society of Environmental Journalists.

EVENTS

Magpie

Since 1973, Terry Leonino and Greg Artzner have brought their unique sound and remarkable versatility to audiences everywhere, featuring traditional and vintage Americana to contemporary and stirring original compositions.

With two strong voices in harmony and superb instrumental arrangements, their sound is powerful and moving. Award-winning recording artists, singers, songwriters, musical historians, playwrights, actors and social activists, Terry and Greg are proud to be, as Pete Seeger said of them, "...more links in the chain", dedicating their lives and music to leaving this world a better place.

Panel Discussion:

The "Michigan's Environment: Challenges for the Future" panel brings together a diverse group of experts on Michigan's environment for a lively discussion of our future. They will offer their insights on the challenges and opportunities we face, and respond to questions from the audience.

Panelists include: **Dr. Debra Furr-Holden** is the Interim Director of the Division of Public Health and Director of the National Institute on Minority Health and Health Disparities (NIMHD)-funded Flint Center for Health Equity Solutions. She also serves as the MSU Co-Director of the Healthy Flint Research Coordinating Center. **Sean Hammond** helps MEC build and maintain relationships with lawmakers, stay abreast of new bills and legislative committee activities, and keep the organization's member groups informed about developments at the Capitol. **Dr. Alan Steinman** is the director of the Robert B. Annis Water Resources Institute, located at Grand Valley State University. He received his PhD in Botany/ Aquatic Ecology from Oregon State University in 1987 and has testified in front of the US House of Representative, Subcommittee of the Interior in December of 2015, regarding invasive species in the Great Lakes. **Jared L. Talley** is a doctoral student in Philosophy. In his doctoral program he is intent on studying the ways in which communities can help to govern their local natural resources. He has worked closely with state and federal resource agencies to further their community engagement practices and hopes to continue impacting effective and ethical management of our environment by promoting this community engagement in policy making. **Helen Taylor** is the State Director of the Nature Conservancy with more than 25 years of experience working in the environmental field and the Great Lakes, she has witnessed first-hand both the evolution of the conservation movement and the Conservancy itself.

Helen Taylor

Debra Furr-Holden

Jared L Talley

Alan Steinman

Sean Hammond

Environmental Science & Policy Program at Michigan State University

Fate of the Earth Morning Workshops

March 24th, 2018 10-10:50am

"Bringing Ethics to Wild Lives: Shaping Public Policy for Barred and Northern Spotted Owls" - *Dr. William Lynn, Clark University.* **Location: Room 105B**

"Connecting with Nature" – *Jenny Mensch, Fenner Nature Center.* **Location: Room 105A**

"Smart Gardening" - *Diane Brown-Rtylewski, Michigan State University Extension Specialist.* **Location: Willy**

"Touring the MSU RISE Program" – *Dr. Laurie Thorp, Michigan State University.* **Location: Bailey Hall**

"Getting Fired Up About Climate Change" *The Meridian Energy Team* **Location: 106**

"Citizen's Climate Lobby: Citizen Engagement and Carbon Pricing Policy" – *Jean Boucher.* **Location: 104B**

"Deep Earth/Deep Ocean: Singing to Save Our Planet" –*Magpie Folk Music Group* **Location: Big Ten A**

"How Do We Know Nature?" – *Jared L. Talley & Shelbi Nahwilet Meissner, Michigan State University.* **Location: 104A**

"What MSU is doing toward Sustainability" – *Dr. Wolfgang Bauer, Michigan State University.* **Location: Heritage**

Check out the full program descriptions at http://www.espp.msu.edu/events/fateoftheearth/2018/program.php

Environmental Science & Policy Program at Michigan State University

Fate of the Earth Afternoon Workshops

March 24th, 2018 2:30 - 3:20pm

"Community Sustainable Living"
Carla Iansiti, Michigan State University
Location: Room 104A

"Connecting with Nature" – *Jenny Mensch, Fenner Nature Center.* **Location: Room 105A**

"Defining Community Supported Agriculture (CSA)" - *Degan Gembarowski & Abigail Kuplicki, MSU Student Organic Farm.*
Location: 104B

"**Fate of Our States**" -*Christy George, Oregon Public Broadcasting*
Location: Big Ten A

"From Couch Potato to Change Agent" - *Terry Link, Peace Education Center,*
Location: Willy

"Michigan's Changing Climate" - *B.J. Baule & GLISA.*
Location: 105B

"Nature Immersion Changes Consciousness" – *MSU Student Greenhouse Project..*
Location: Heritage

"**Nature/Environment and Yoga** - Caitlin Kirby, Michigan State University.
Location: 106

Check out the full Fate of the Earth program descriptions at http://www.espp.msu.edu/events/fateoftheearth/2018/program.php

Goodbye Drs. Jinhua Zhao and

Dr. Jinhua Zhao, Professor of Economics, will complete his final year as Director of the Environmental Science and Policy Program this August. After starting a sabbatical in August, he is looking forward to working on his ongoing research projects and starting new one. Following his sabbatical, Dr. Zhao will return to teaching as well.
Several MSU leaders look back on his time as leader of this unique interdiscipiliary program:

Dean Rachel Croson: Director Zhao's term has been energetic and enthusiastic. Under his leadership ESPP moved from a doctoral specialization to a dual doctoral major. He led ESPP to spearhead the innovative WaterCube project, creating an innovative market mechanism to allocate seed funding to interdisciplinary teams. And he launched the successful Fate of the Earth Symposium, now entering his fifth year. Director Zhao's creativity and willingness to innovate has enhanced the value of ESPP, and of MSU as a whole.

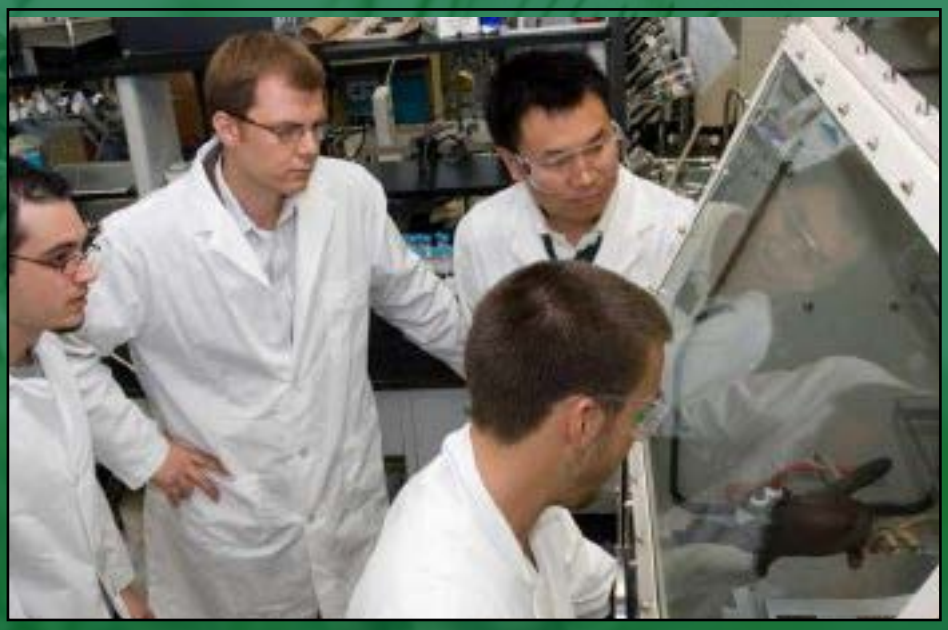
Associate Director Vlad Tarabara: How ESPP has transformed since 2012 is perhaps better seen from outside. As someone who's been a part of the internal workings of the program, I can say that I greatly appreciated the program's "microclimate" - that of collegiality, mutual support and the sense of a common mission. I've learned quite a bit from him. I would like to thank Jinhua for being an excellent colleague and for his service, through leadership, to our community.

Founding Director Tom Dietz: Jinhua has done a truly remarkable job as director, moving ESPP into a respected position as the central node in the network of environmental research and graduate education at MSU. Several exceptional accomplishments stand out.
Building on the initial set of ESPP hires, he has led the Program into the position of trusted steward of interdisciplinary hiring initiatives. Interdisciplinary hires and especially those brought together as a cluster are essential for the 21st century university. But to be successful they require a careful balance across multiple units and interests. And once faculty are hired, special efforts are required to ensure that collaborative links are formed. Jinhua has done a superb job of leading a very important series of hires at MSU and in developing the activities that insure that the new hires will collaborate to create the synergies that come from crossing disciplinary lines.
Moving the ESPP doctoral program to the status of a dual degree program fulfills an intention in place since the start of the program 15 years ago. The goal of ESPP graduate education is to help student learn to become fluent in communicating across disciplines and learning from each other. The multiple student driven activities that Jinhua has fostered has led to amazing success in nurturing skills at interdisciplinary collaboration in our students.

Vlad Tarabara. And Thank You.

Because of Jinhua's leadership, ESPP has received its first substantial endowment. With that endowment and his encouragement, ESPP is developing a much more robust engagement with the larger MSU and Michigan communities. The annual Fate of the Earth Symposium and the Donald Koch Distinguished Lecture Series will be an ongoing process of engaging with and learning from the broader Michigan community.

We, **the staff of ESPP,** are deeply appreciative for all Dr. Zhao has done for the program, taking it in new and exciting directions. His combination of vision and leadership, together with his ability to value the input of all, has made the program a success for students, faculty and staff. We wish him the very best as he starts on the next stage of his academic career.



Dr. Vlodymyer Tarabara is also leaving his position as associate director, after five years in the position. He plans to spend more time working closely with his research group members and continue to teach Environmental Engineering.

ESPP Director Jinhua Zhao:
Vlad has been instrumental in the success and growth of ESPP. He has great ideas, is a wonderful team player, and worked hard to make sure that our goals are accomplished in efficient and equitable manners. He brings unique perspectives from his background as an interdisciplinary researcher in environmental engineering.

Dr. Tarabara has been integral in every aspect of ESPP from its wide-ranging vision to its minute details and commitment to excellence. The staff of ESPP wishes him well in the future and will miss his humor and insight.

GRADUATE STUDENT SPOTLIGHT

DYLAN BREWER, Economics and ESPP

Major/Research Area: PhD, Economics
Biosketch: I received my bachelor's degree from the University of Virginia with double majors in Economics and Foreign Affairs and a minor in Math. My research interests lie in the intersection of property rights economics and environmental externalities. Applying market tools to the environment can have impressive results in affecting positive environmental stewardship. I am interested in studying property institutions that allow individuals to turn environmental quality into an asset. When it is profitable to take care of the earth, people tend to come up with great ways to do so. In the past, I have contributed to research projects studying private conservation easements and city-grid land demarcation.

Dylan, who was appointed to serve on the ESPP Graduate Program Council last year, talked with ESPP student aide Lauren Carr.

Q: Where are you from and why did you want to go to the University of Virginia for your bachelor's degree?
A: I was born in Owosso, Michigan but I went to high school in Ohio. I chose the University of Virginia because it was the school that worked out financially and later on, I found out that they have a great Economics department.

Q: What drew you to Michigan State and ESPP?
A: I was doing an internship in Montana where I fell in love with environmental economics and how people manage their property. I heard about the economics department and Dr. Jinhua Zhao, the director of ESPP, and how this program was working hard to have seemingly opposite fields come together to solve environmental issues such as climate change.

Q: You already have so many responsibilities as a PhD student in the Economics department. What made you want to be the student representative for the graduate program council.
A: I was actually contacted by Dr. Zhao, who has been my professor for a few of my classes here at Michigan State, and he asked me if I wanted to be the student representative since the most recent representative had just graduated from the program.

Q: What do you hope to accomplish with the graduate program council?
A: I really want to bring in people to ESPP who are curious about both social and environmental sciences but who are also cognizant of the associated realities.

Q: Your profile says that your bachelor degree from the University of Virginia with a double major in Economics and Foreign Affairs. Why did you choose Foreign Affairs even though you are getting your PhD in Economics?
A: Foreign affairs and economics tend to work together quite well. As a foreign affairs major, you tend to read quite a few economics studies in those types of classes because numbers and statistics are associated as facts.

Q: Have you picked a topic for your dissertation yet? If so, what is it? If not, what options are you considering?
A: My dissertation is about the effect of contracts in rental housing for energy usage. This can become quite complicated because of a sorting effect. Although a person might be looking at a specific apartment in East Lansing, they are already sorted into a certain category based on their energy usage before they even talk to a landlord about renting.

Q: What are your plans after you successfully defend your dissertation?
A: I hope to move on to a career as a professor in economics. However, I would not be opposed to working in an interdisciplinary field such as the Environmental Science and Policy Program.

Q: Where do you see yourself in 10 years?
A: I hope to be in academia as an economics professor but I hope to be doing some work in Washington, working with legislators to create both carbon and pollution taxes. Economists have actually proven that this is the best way to combat climate change from a legislative standpoint. Through my research, I have concluded that environmental policies can have negative effects so they need to be designed intelligently.

Q: What inspired your current research endeavors?
A: It's actually kind of a funny story. After I completed my first year as a doctoral student, I started renting a condo in East Lansing. When I received my first utilities bill, I realized that I had to pay for electricity but I did not have to pay for water. Naturally I asked myself, "why is this the case?"

Q: Any interests outside of Economics and Foreign Affairs?
A: Since I have been doing my internship in Bozeman, Montana for the summer, I have really started to get into hiking. Also, I really enjoy college football since I go to a Big Ten school!

Q: Any advice for anybody wanting to go for a PhD?

A: Don't be afraid to make friends and to make connections. And above all else, work hard!

Dual Major in Environmental Science and Policy to start in Fall of 2018

This spring, ESPP was pleased to announce that the request to transition our Doctoral Specialization in Environmental Science and Policy into a doctoral Dual Major received final approval from university administration. The Dual Major in Environmental Science and Policy is in partnership with about 20 departments and schools at MSU, and will be effective in Fall 2018.

Environmental Science and Policy Dual Major

Doctoral students who have been accepted into the partner departments and schools will be able to enroll in Environmental Science and Policy as a second major and have both majors appear on their diplomas and transcripts. The dual major highlights the interdisciplinary training and more appropriately matches the credentials of our students. It represents another milestone in our efforts to establish graduate education programs that are innovative, interdisciplinary and campus wide.

The Dual Major is designed to continue the formula of a T-shaped graduate education that has guided ESPP from the start. The approach reflects the belief that environmental professionals need both interdisciplinary breadth and disciplinary depth, allowing them to communicate across different fields of knowledge. The program aims to develop experts who understand the context of their research and can work effectively in multidisciplinary teams.

To complete the Dual Major, students take ESP 800: Principles of Environmental Science and Policy, a team-taught course that covers the scholarship and key research questions in the intersection of environmental science and policy.

This is followed by a pair of interdisciplinary courses in a modular format. In ESP 801: Physical, Chemical, and Biological Processes of the Environment, students receive a broad overview of environmental science from the perspectives of natural sciences and engineering. The learning modules include Environmental Geosciences, Biology/Ecology, Environmental Chemistry and Environmental Engineering.

The counterpart of ESP 801 is ESP 802 "Human Systems and the Environment". This course offers a broad overview of environmental policy from the perspective of the social sciences, including Sociology, Economics, Anthropology and Geography. In the fourth course, students complete a Capstone Experience that puts the interdisciplinary training to practice by addressing real world environmental science and policy questions.

Finally, as a part of the Dual Major, students will pass a written examination demonstrating knowledge of environmental science and policy, and integrate environmental science and policy into their dissertation.

We are excited about the new opportunities provided to our students under the newly established Dual Major. For more information, please visit http://www.espp.msu.edu/education/dual_major.php.

Introducing ESPP Partner Programs

As part of our transition from doctoral specialization to Dual Major, ESPP has signed agreements with more than 20 schools and departments who are willing to partner with ESPP and allow their PhD students to enroll in the ESP Dual Major.

The academic benefits of the dual major to students include opportunities to interact with others from different discliples, form research partners from across the campus and gain the ability to communicate and work in both natural and social science circles. If you are interested in becoming a partner program, please contact us at essp@msu.edu.

ESPP is proud to have partners across six colleges including:

College of Agriculture and Natural Resources
- Agriculture Food and Resource Economics
- Biosystems & Agricultural Engineering
- Community Sustainability
- Fisheries and Wildlife
- Forestry
- Horticulture
- Packaging
- Planning, Design and Construction
- Plant, Soil and Microbial Sciences

College of Arts and Letters
- Philosophy

College of Communications Arts and Science
- Communication
- Journalism
- Media Information

College of Engineering
- Biosystems & Agricultural Engineering
- Civil and Environmental Engineering

College of Natural Science
- Earth and Environmental Science
- Integrative Biology
- Microbiology and Molecular Genetics
- Plant Biology

College of Social Science
- Anthropology
- Criminal Justice
- Economics
- Geography, Environment and Spatial Sciences
- Sociology

Partner Program Spotlight

School of Planning, Design and Construction

Doctoral Program: Planning, Design and Construction
The Doctor of Philosophy in Planning, Design and Construction with a concentration in construction management, environmental design, or urban and regional planning will enable students in the School of Planning, Design and Construction to meet future challenges. Graduates of this program will possess the knowledge and skills necessary to understand the effects of plans, regulations, design, materials, project management techniques, and construction systems on the economic, environmental, and social concerns of stakeholders and society.

Director: **Dr. Ming-Han Li**

COMMUNITY

WHERE ARE THEY NOW?

An update on ESPP Alumni

Ellis Adams (Geography, 2016)- Assistant Professor, Global Studies Initiative, Georgia State University
Stephen Aldrich (Geography, 2009)- Assistant Professor, Department of Geography, Indiana State University
David Bidwell (Sociology, 2008)- Assistant Professor, Marine Affairs, University of Rhode Island
Victoria Campbell-Arvai (CARRS, 2009)- Assistant Research Scientist, School of Natural Resources & Environment, University of Michigan
John Clements (Sociology, 2013)- Research Manager, Department of Research, Central Michigan University
Saul Daniel Ddumba (Geography, 2014)- Founder and Chairman of Redan Consults
Micaleila Desotelle (Zoology, 2017)- Department of Integrative Biology, Michigan State University
Robert Drost (Geological Sciences, 2014)- Assistant Professor, Integrative Geosciences, Michigan State University
Matt Grisko (Philosophy, 2011)- Learning Assistant, Roger Parks Montessori Schools
Richard Grogan (CARRS, 2010)- Regional Director, New Hampshire Small Business Development Center
Ryan Gunderson (Sociology, 2014)- Assistant Professor, Sociology and Social Justice Sciences, Miami (OH) University
Erin Haacker (Geological Sciences, 2017)- Research Associate, Daugherty Global Institute, University of Nebraska
Kim Hiller-Connell (Human Environment: Design and Management, 2005)- Assistant Professor, Apparel and Textiles, Kansas State University
Ellen Holste (Forestry, 2016)- Program Coordinator, Pierce Cedar Creek Institute
Marcia Jnbaptiste (Crop and Soil Sciences-Environmental Toxicology, 2006)- Research Scientist, USDA, Agriculture Research Service
Jason Karl (Fisheries and Wildlife, 2008)- Research Ecologist, USDA-ARS, Jordana Experimental Range
Jennifer Kelly (Sociology, 2015)- Visiting Associate Professor, Department of Sociology, Michigan State University
Thitisilp Kijchavengkul (Packaging, 2009)- Post-doctoral researcher, Packaging, Michigan State University
Nicole Lamp (Fisheries and Wildlife, 2007)- Biologist, US Fish and Wildlife Service
Zarraz Lee (Microbiology and Molecular Genetics, 2011)- Post-doctoral Research Scientist, School of Life Sciences, Arizona State University
Shengpan Lin (Integrative Biology, 2017)- Postdoctoral Fellow, Department of Integrative Biology, Michigan State University
Abigail Lynch (Fisheries and Wildlife, 2013)- Research Scientist, National Climate Change and Wildlife Center, USGS
Erin Maloney (Communications, 2010)- Research Director, Message Core, Center of Excellence in Cancer Communication Research, Annenberg School of Communication, University of Pennsylvania
Elizabeth Mauritz (Philosophy, 2008)- Doctoral Student, Philosophy, Michigan State University
Colleen McLean (Environmental Geosciences, 2010)- Assistant Professor, Geological and Environmental Sciences, Youngstown State University
Max Melstrom (Philosophy, 2011)- Associate Professor, Institute for Environmental Sustainability, Loyola University

Jakob Nalley (Zoology, 2016)- Researcher, Department of Integrative Biology, Michigan State University
Norbismi Nordin (Packaging, 2013)- Department of Process and Food Engineering, Universiti Putra Malaysia, Putrajaya
Emily Norton (Fisheries and Wildlife, 2005)- Open Campus Coordinator, Oregon State University
Linda Novitski (Zoology, 2013)- Assistant Researcher, University of Michigan
Perdinan (Geography, 2013)- Lecturer, Department of Geophysics and Meteorology, Bogor Agricultural University in Indonesia
Carson Reeling (AFRE, 2015)- Assistant Professor, Department of Economics and Environmental Sustainability, Western Michigan University
Allison Rober-Wyatt (Zoology, 2012)- Assistant Professor, Environmental Biology, Ball State University
Leilei Ruan (Crop and Soil Sciences, 2011)- Research Associate, Department for Environmental Science, Policy, and Management, University of California, Berkeley
Kateri Salk (Zoology, 2017)- Postdoctoral Fellow, University of Waterloo
Carolina Santos (Geography, 2015)- Postdoc Fellow, Michigan State University
Krishna Shrestha (CARRS, 2008)- Policy Advisor, Ministry of Government Services, Ontario Public Service
Rachael Shwom (Sociology, 2008)- Assistant Professor, Climate and Society, Rutgers University
Samuel Smidt (Geological Sciences, 2017)- Visiting Assistant Professor, Department of Geology and Environmental Sciences, Wheaton College
Sara Syswerda (Crop and Soil Sciences, 2009)- Field Station Director, Pierce Cedar Creek Institute
Lisa Szymecko (CARRS, 2012)- Research Area Specialist Intermediate, Center for Bioethics and Social Sciences in Medicine, University of Michigan
Sara Tanis (Forestry, 2011)- Visiting Assistant Professor, Biology, Kalamazoo College
Sheldon Turner (Geological Sciences, 2013)- Environmental Science Faculty, Triton College
Mamta Vardhan (CARRS, 2009)- Sessional Lecturer, Agricultural, Life, and Environmental Sciences, University of Alberta, Edmonton
Pariwate Varnakovida (Geography, 2009)- Director, KMUTT Geospatial Engineering and Innovation Center (Bangkok, Thailand)
Cameron Whitley (Sociology, 2017)- Program Coordinator, Rutgers University - Camden
Leigh Whittinghill (Horticulture, 2013)- Professor, Department of Urban Agriculture, Kentucky State University
Wu Yang (Fisheries and Wildlife, 2013)- Professor, Department of Environmental Policy and Sustainability, Zhejiang University-China
Barbara Zawedde (Horticulture, 2013)- Coordinator, Uganda Biosciences Information Center

Information compiled by ESPP Student Aide Lauren Carr

FACULTY SPOTLIGHT
Dr. **Prabhat Barnwal**, Department of Economics
Assisant Professor of Economics and ESPP

Dr. Barnwal discussed his move to MSU with ESPP Student Aide Lauren Carr:

Your academic career has pretty much spanned all over the globe, so why did you choose to take a position at MSU and with ESPP?

MSU is actually quite global with such a diverse student body and the international research carried out by faculty here. Further, given my research interests in environment and development, it was a fairly easy decision to come here to work with ESPP and the economics department at MSU.

Why did you choose to further your academic career in three completely different countries?

It was less by design than by force of circumstances. After my undergrad in electrical engineering in India, I worked as a shop floor manager with General Motors in India. My interest in economics primarily started taking shape there, and I applied to a couple of masters program abroad. Then, the International University of Japan provided me an excellent opportunity -- generously funded by the Konosuke Matsushita Memorial Foundation -- to study economics in Japan. Since most of the faculty there had doctoral degree from US, I got to know more about PhD programs in US and eventually landed at Columbia University. The journey just could not be better than this.

What classes do you teach here at MSU?

I teach EC 450: Economics of Environmental Policy and EC 499: Senior Seminar in Development Economics. EC 450 is about how economics can be applied to solve complex environmental challenges. In EC 499, we discuss big questions in development economics, review related research papers and methodologies, and students work on their research projects.

What do you hope to accomplish with MSU and ESPP both as a researcher and as a professor?

As a researcher, I hope to actively contribute to the research environment here. My teaching responsibilities regularly bring new challenges in terms of explaining sophisticated concepts and inculcating interest for modern economics in bright young students, which I enjoy greatly and would continue to do so.

What are your current research endeavors?

My research is in applied microeconomics with a focus on environmental and development economics, and policy evaluation. Most of my research has an international focus, and more than half of my ongoing projects -- mainly field and primary data-based projects, are related to India. There is also a couple of policy evaluations ongoing in collaboration with the government in India. For instance, in one project I am looking at ways to improve delivery of subsidies to citizens in India. In a completed project with a group of co-authors, I studied the demand for information on arsenic contamination in water, and how the information leads to behavioral changes. Then, there are big questions of global importance which require putting together multiple datasets from a large number of countries -- e.g., my research on health-wealth trade off of mineral mining in developing countries and the welfare impact of modern crop varieties. Close to home, I am working with a group of economics faculty and PhD students on measuring the socio-economic impact of investment in public lighting infrastructure in Detroit.

What was the inspiration for these topics?
The main inspiration comes from the observation that existing policies in developing countries are often inefficient by design and/or in practice. An evidence-based approach to policy making can bring in a lot of positive change. I find it fascinating how the empirical methodologies developed in economics to estimate causal effects, can help in rigorously answering critical questions, which have potential to directly improve the well-being and life experience of people.

What connections have been made in your research in relation to the environment and development thus far?

The weekly and bi-weekly seminars in the economics and AFRE departments are extremely helpful for getting feedback on research. We also have bi-weekly Energy Economics Lab (EEL) meetings, where we discuss and collaborate on research related to energy and environment.

Where do you see yourself in ten years?
I hope to continue doing my research and teaching, and expect to carrying out more policy-relevant work building upon my academic research.

Any advice for anybody getting a PhD?
I believe working for a PhD degree is similar to having a very demanding full time job. I can provide two suggestions. First, it would help if one keeps an eye at research while doing the course work in initial years. Second, it is important to also invest in soft skills.

ESPP students

Jelili Adebiyi (Community Sustainability)- Milton Steinmueller Fellowship in Natural Resources and Environmental Policy; College of Graduate Students Disciplinary Leadership Award, Michigan State University; Michigan State University, College of Agriculture and Natural Resources Alumni Association Scholarships; Gender, Justice and Environmental Change Dissertation Research Fellowship; Research Enhancement Award; Miriam J. Kelley African Scholarship Grant Program; Fellow/Future Leader in International Agriculture, The Association for International Agriculture and Rural Development (AIARD); Inaugural Recipient, MSU Outstanding Doctoral Mentor Award

Dee Jordan (Geography, Environment and Spatal Sciences) - Excellence in Diversity Award for Individual Emerging Progress; an Alliance for Graduate Education and the Professoriate (AGEP) Scholar Award; selected to serve on the Dean's Advisory Board for Diversity and Inclusion

Apoorva Joshi (Journalism) - the Theodore Roosevelt Conservation and Environmental Leadership Fellow; the Don Caldwell Memorial Scholarship in Environmental Journalism.

Dipti Kamath (Civil and Environmental Engineering)- ISIE-ISSST 2017 Conference Poster Competition, Chicago

Caitlin Kirby (Geological Sciences)- Lyman Briggs College Scholarship of Undergraduate Teaching and Learning Fellowship; Geoscience Education Division Travel Award; Earth and Environmental Sciences Travel Award

Lin Liu (Geography, Environment and Spatial Sciences)- Travel Grant from the Future Leaders Forum Scholarship to attend the Future Leaders Forum hosted by the Association for International Agriculture and Rural Development (AIARD) and to give a talk at the AIARD's 53rd Annual conference in Washington D.C. 2017.

receive accolades

Bonnie McGill (Integrative Biology)- Outstanding Student Poster Award at the American Geophysical Union conference in December; David H. Smith Conservation Research (Postdoc) Fellowship

Rebecca Minardi (Community Sustainability) – Foreign Language and Area Studies Fellowship

Hogeun Park (Urban and Regional Planning) - SESYNC Graduate Research Fellow from the National Socio-Environmental Synthesis Center

Rajiv Paudel (Geography, Environment and Spatial Sciences)- The Lawrence and Marjorie Sommers Fellowship for International Travel Research

Steve Roels (Integrative Biology)- College of Natural Sciences Dissertation Completion Fellowship

Udita Sanga (Community Sustainability)- SESYNC Graduate Research Fellow from the National Socio-Environmental Synthesis Center

Yike Shen (Plant, Soil and Microbial Sciences) - Institute for Integrative Toxicology Summer Travel Award; American Society for Microbiology Travel Award.

ESPP Founding Director named University Distinguished Professor

ESPP and Sociology Professor Thomas Dietz has been named a University Distinguished Professor in recognition of his achievements in the classroom and community. Dr. Dietz is also a professor of animal studies and has served as associate dean in the colleges of Social Science, Agriculture and Natural Resources, and Natural Science, and as assistant vice president for environmental research at Michigan State University.

Upwelling Brines and Groundwater Resource Development – A System-based Investigation of Groundwater Sustainability in the Lower Peninsula of Michigan

By Zachary Curtis, doctoral student in Environmental Engineering and Environmental Science and Policy (advisor: Dr. Shu-guang Li)

Background

The State of Michigan - although surrounded by the Great Lakes – relies heavily on groundwater to support its different water-use sectors. Over 700 million gallons are withdrawn each day to support agricultural and industrial activities and provide drinking water supplies to roughly half of all Michigan citizens. There are, however, limitations to potable groundwater supplies in regions of the State, particularly in the low-lying and coastal regions of the Lower Peninsula (LP). In these areas shallow saline groundwater occurs, in many cases making the groundwater unfit for human consumption and for agricultural uses and detrimental to the environment. Based on analysis of groundwater chemistry from sites in east-central LP of Michigan and a few other scatted locations, researchers have suggested that the salinization is due to upward movement of brines – or hypersaline pools of groundwater in the deep geologic formations. In recent years, Ottawa County – which resides in the low-lying coastal area of west-central LP of Michigan – has reported elevated groundwater salinity in water wells. Ottawa also happens to be the fastest growing county in Michigan, and unchecked increases in groundwater withdrawals have been used to support rapid population growth and expanded agricultural activities. These observations prompted officials at the township, county and state levels to ask:

- Are the scattered occurrences of saline groundwater across LP of Michigan related? (Is brine upwelling systematically impacting low-lying areas across the LP of Michigan?)
- How has pumping impacted the amount groundwater availability in our shallow aquifers? (Have increases in groundwater pumping triggered groundwater salinity problems, e.g., in Ottawa County?)
- What is the long-term sustainability of our groundwater resources? (How can we best manage our groundwater resources while promoting growth and development?)

Collaborative Study

A large-scale, 4-year study was completed through cooperative efforts between different stakeholders, researchers, planners, and outreach specialists Michigan State University (MSU) and Ottawa County, with a goal to understand and characterize the integrated groundwater quantity and quality dynamics associated with the brine upwelling process. The specific parties involved were:

- *MSU Dept. of Civil and Environmental Engineering* (CEE). Led by Professor Shu-guang Li and Zachary Curtis, ESPP student and environmental engineering Ph.D. candidate - this team was responsible for compiling datasets for statewide analysis and developing groundwater flow simulations to better understand the Ottawa County aquifer system. They also led the execution of a large-scale field sampling campaign in Ottawa County, which included MSU postdocs, graduate students, and more than 50 undergraduate students. Key members of the team included: Dr. Phanikumar Mantha, Dr. Hua-sheng Liao, Dr. Prasanna Sampath, and Dr. Guoting Kang.
- *Ottawa County Planning and Performance Improvement Department (PPID)*. The Ottawa PPID team organized and facilitated routine meetings between the MSU groundwater research team and the Groundwater Task Force – an external committee of technical experts, stakeholders (e.g., well drillers) and managers/decision-makers at the township, county, and state levels. They also provided key data/ information needed to analyze water groundwater dynamics in Ottawa County.
- *MSU Institute of Water Research (IWR)*. Specialists from MSU IWR developed a web-based decision support system (DSS) designed to assist with site-scale analyses and decision-making within the county. They also created a management guidebook for the county and a statewide action plan based on the modeling and analysis completed by the groundwater research team (see Shaping Policy below). Key members included Dr. Jon Bartholic, Laura Young, Jason Piwarski, and James Duncan.
- *Dr. Dave Lusch (Dept. of Geography, Environment, and Spatial Sciences)* was also involved in major aspects of the project.

The research assimilated a variety of groundwater data sources, including high-density, statewide water wells datasets that are often that was often deemed by many as too noisy and too crude to be useful. Part of Zach's dissertation work focused on a novel approach that allowed uncovering hidden complex patterns in groundwater flows – from statewide scale to regional scale to local scale – using these statewide databases. This work helped to confirm that brines are systematically impacting low-lying areas where groundwater is discharging.

The study also developed and applied a data intensive modeling approach that allows simulating the complex interplay of the natural upwelling processes, human activities (associated with agriculture and food production), and climate change. By combining field sampling, data mining, geologic/geostatistical modeling, and process-based hydrological modeling, the research team demonstrated that local-scale impacts of brine

upwelling in Ottawa County are controlled by : i) streams and rivers – which act as 'natural pumps' that bring deeper groundwater to the surface; ii) the occurrence of nearly impervious geologic material at the surface – which restricts freshwater flushing of deeper groundwater; and iii) the space-time evolution of water well withdrawals – which, over time, induces migration of saline groundwater from its natural course. Screening-level evaluation of water quality, subsurface geology and groundwater flow patterns in 33 other counties identified as 'at risk' revealed that many of the issues facing Ottawa County are being experienced in the other low-lying counties across LP of Michigan.

Guiding Future Management

These findings triggered an urgent response from local government officials to reduce/reverse the negative impacts on the groundwater system in coming years of growth and development. Using carefully planned projections of groundwater use and land use/land cover change developed by planners from the Ottawa County Planning and Performance Improvement Department (PPID) and Ottawa County Public Utilities Department, the calibrated groundwater model was applied to explore groundwater conditions for the next 20 years (2015-2035). This 'future modeling' effort identified areas prone to groundwater shortages and/or problematic levels of groundwater salinity, and will help guide the development of a long-term groundwater monitoring network needed to refine/verify the modeling results and steer adaptable management of the county's groundwater resources.

Shaping Policy

A key aspect of this large-scale collaborative project was to disseminate the key findings and practical management implications to relevant persons so that sound policy decisions can be made moving forward. In December 2017, Zach and MSU CEE presented to stakeholders and decision-makers from Ottawa County and the Michigan Department of Agriculture and Rural Development. Zach will also present findings at the Annual Conference of the International Association for Great Lakes Research on June 19, 2018. Two detailed technical reports on the statewide and Ottawa County modeling efforts were developed by MSU CEE, and MSU IWR recently developed both a statewide action plan (with a suggested prioritization of future study areas) and groundwater management guidebook for Ottawa County based on the modeling results. The distribution of this wealth of meaningful information will help inform decision-makers, planners and resource managers charged with protecting and sustaining groundwater resources in Michigan and beyond.

Zachary Curtis receives Outstanding Graduate Student Award

By Sierra Jankowski, ESPP Student Aide

ESPP is proud to announce that our doctoral specialization student Zachary Curtis has been named Outstanding Environmental Engineering PhD student.

Zach is currently earning his PhD in Environmental Engineering. Before pursuing his PhD, he obtained a Bachelor of Science degree in Astrophysics; participated in summer research in Boulder, Colorado; did brief studies at Boston University; and received a Master of Science degree from Michigan State University in Environmental Engineering.

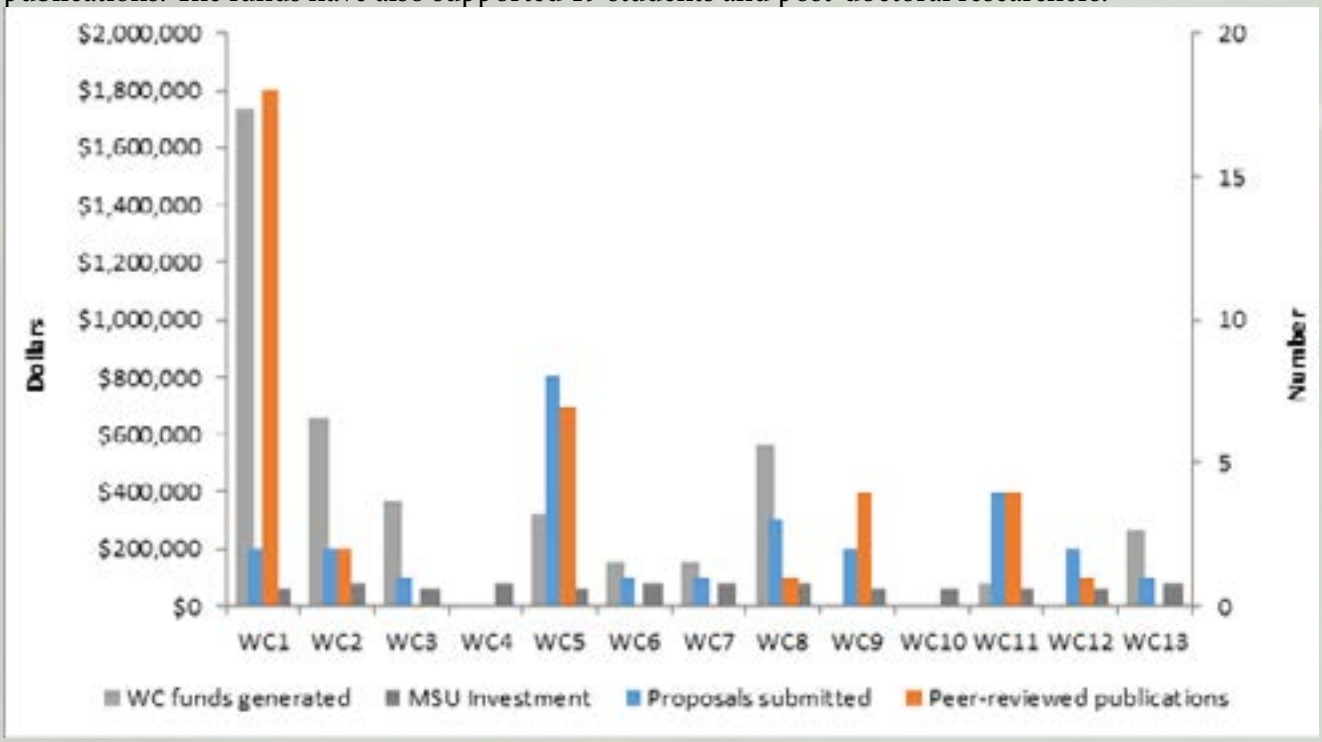
His goal during his graduate study is to help communities develop and better understand water sustainability. For his PhD research he is using groundwater and watershed modeling for brine upwelling into lowland and coastal areas of Michigan. Along with his research, Zach is a Teaching Assistant for the CoRe Engineering program in the College of Engineering. His advisor is Dr. Shu-Guang Li.

Zach received the Outstanding Graduate Student Award from the Department of Civil and Environmental Engineering's Graduate Studies Committee. This award is given based on the student's grade point average, quality of research, and his character as a citizen. Zach will receive a plaque and a money award.

WaterCube success continues

In 2015, the inaugural WaterCube program supported 13 new teams of faculty. The WaterCube program was designed by the MSU Water Science Network to stimulate new interdisciplinary collaborations and novel water research ideas. All WaterCube teams are multidisciplinary and contain faculty from at least two colleges (5 WaterCubes involve three colleges and 8 involve two colleges). They also include 25 assistant professors, 12 of whom were hired as part of the Global Water Initiative. Since 2015, the teams have been hard at work developing their new water research ideas and the results have been impressive.

These teams have developed exciting new ideas, from micro-robots that treat pollutants to new methods for managing water use. The teams have generated over $4 million in external grants and produced 37 peer-reviewed publications. The funds have also supported 19 students and post-doctoral researchers.



The WaterCube program was successful in creating new collaborations and stimulating MSU water research. The grantees noted the value of the program in their final reports:

- ***The WaterCube program clearly afforded an opportunity for the three PI's to collaborate that would not likely have happened otherwise.***
- ***The WaterCube funding has been instrumental in the fruition of this exploratory research. It is likely that [our] research would have never happened without it.***
- ***The WaterCube funding provided a valuable resource for our team in that it served to create an environment where geomicrobiologists, public health microbiologists, hydrogeologists, and bioinformaticists could bring to bear their unique expertise on a focused research problem.***

ESPP-AgBioResearch Interdisciplinary Team Building Initiative

ESPP and AgBioResearch are pleased to continue the Interdisciplinary Team Building Initative (ITBI) funding program. In addition to the traditional format of providing funding to promote new collaborations between faculty researchers from different disciplines, ITBI has also been expanded to include a second tier of funding.

Tier 1

An ITBI Tier 1 grant will provide funding for two years with a total amount of up to $10,000. The funds can be used for group meetings, workshops, campus visits for potential collaborators and seminar speakers, site visits,travel to funding agencies, identification of and responses to grant opportunities, preliminary research, etc.

Tier 2

An ITBI Tier 2 grant will provide funding for two years with a total amount of up to $100,000. Successful Tier 1 teams that have demonstrated effective collaboration and team building and identified major funding opportunities to pursue will be eligible for potential funding via the Tier 2 grant mechanism. Successful Tier 1 teams will be invited to make a presentation with their vision for a Tier 2 project, and will be given the option to expand their team and collaborative activities. Tier 2 projects will be required to focus on major funding opportunities. Funding will be provided to support activities such as preliminary research and data collectionand research teams are encouraged to leverage the ITBI funds to other opportunities. Project plans must include specific timelines of activities and expenses of the funds.

Deadlines are April 15 and December 1, annually.

Visiting Scholars To Advance Science Grants

New! ESPP is excited to annouce a third round of VISTAS funding for 2018.
Visiting Scholars to Advance Science (VISTAS) grants are designed to increase networking opportunities for MSU faculty, bring world-class experts to MSU, and facilitate development of multi-University research proposals in the areas of environmental science, technology, and policy.
The VISTAS grants aim to provide support for scholars from other universities and institutions to visit MSU to develop externally funded research proposals jointly with MSU researchers. The grants will cover transportation, housing and perdiems for the visiting faculty, allowing them to spend quality time to work with MSU colleagues. VISTAS funding is different from typical seminar support programs and feature longer visiting periods, more intensive interactions with MSU researchers, and explicit goals toward grant proposals. Typical awards are $3,000 for domestic visitors and $4,000 for international visitors.

Deadlines to apply are February 1, May 1 and September 30, 2018.

The role of policy as an adaptive feedback for addressing reactive nitrogen issues in the Mississippi River Basin

By Riva C.H. Denny and Kateri R. Salk
Michigan State University

INTRODUCTION

Environmental issues in the 21st century are exemplified by an intersection of social and biophysical factors. Given the interdisciplinarity of these issues, solutions will only be achieved through successful integration of multiple disciplines (Dong et al. 2010, Liu et al. 2007a). The critical need for this approach has been recognized, and its prioritization is illustrated by funding programs through funding agencies (e.g., NSF Dynamics of Coupled Natural and Human Systems), and cross-disciplinary institutional programs (e.g., Michigan State University Environmental Science and Policy Program). One such contemporary environmental issue is the presence of excess nitrogen (N) and phosphorus (P) in surface waters that can cause eutrophication, harmful algal blooms, and hypoxia (Carpenter et al. 2011, Howarth et al. 2011). These water quality impairments can have great economic and environmental costs in freshwater and estuarine ecosystems (Dodds et al. 2009, Smith and Schindler 2009). There are a number of both point and non-point anthropogenic sources of N and P to aquatic systems, including municipal sewage systems, urban storm water run-off, industrial processes, atmospheric deposition, and agriculture (Carpenter et al. 1998).

In this paper, we focus on the role of N from agricultural sources in the Mississippi River Basin (MRB) on water quality impairments in the Gulf of Mexico. We approach this problem by considering social and biophysical systems simultaneously, deemed social-ecological systems (SES) or coupled human and natural systems (CHANS) approaches (e.g., Folke 2006, Liu et al. 2007a). Issues related to agricultural N have been noted as ideal systems in which to apply an SES or CHANS approach due to the tightly coupled interactions among biophysical, sociological, and economic factors (Stuart et al. 2015). Within this approach, we examine policy as a feedback between biophysical and social components of the agricultural N system.

SES AND CHANS

The terms SES and CHANS developed out of an interest in sustainably supporting human populations while preserving natural resources and services. Both concepts also emphasize that human societies and the environment interact and need to be considered simultaneously. SES and CHANS recognize that social and ecological systems are part of one complex system that contains indirect, reciprocal, and feedback effects across multiple spatial and temporal scales (Janssen and Ostrom 2006). While the two terms are often used interchangeably, their origins and conceptual emphases differ.

The SES concept developed from work by Holling (1973) on resilience in ecological systems by extending the idea of resilience to social-ecological systems. Conceptually and empirically, SES emphasizes concepts including resilience, adaptation, vulnerability, and forms of resource use and management (Walker et al. 2004,

Folke 2006, Berkes 2007, Colding et al. 2008). Resilience is a system's capacity to experience disturbances but maintain its structure and function, including feedbacks (Walker et al. 2004, Folke et al.2010). The concept of resilience recognizes that systems are constantly changing and specifically must change in order to maintain their structure and function. The amount of change a system can undergo and maintain its structure and function is its adaptability or adaptive capacity, a quality that is dependent on the capacity of the actors in the system to adapt to changing conditions and thus influence resilience (Walker et al. 2004). Vulnerability is the degree to which a system experiences a negative outcome as a combined result of exposure to a disturbance and the system's resilience (Turner et al. 2003a; Berkes 2007).

Resource management in an SES perspective has the goal to maintain or increase the resilience of a system, including both ecological and social aspects. To accomplish this goal, the resilience perspective advocates for the use of adaptive management, which views policies and management strategies as preliminary approaches through which managers, policy makers, and institutions learn about the system and the effects of employed strategies. Strategies may then be adjusted as needed (Berkes and Folke 1998). While adaptive management focuses on connecting environmental conditions with the policies intended to manage them, adaptive comanagement adds a collaborative social element into adaptive management by incorporating organizations and institutions at multiple levels to create flexible, locally specific approaches to managing complex systems that incorporates both ecological and social feedbacks (Olsson et al. 2004, Folke et al. 2005). Adaptive comanagement is facilitated by adaptive governance, in which management authority is shared across multiple institutions that operate at multiple scales, allowing, for instance, institutional responses at local scales that maintain connections to the larger context (Folke et al. 2005).

CHANS developed from the work of Turner et al. (2003a, b) and Liu et al. (2007a), who drew on a call by the National Research Council to seek connections among scientific research, technological development, and sustainability (NRC 1999). CHANS utilizes key concepts from SES, such as vulnerability, thresholds, and feedbacks (Liu et al. 2007a, 2007b), but typically with a lower degree of conceptual or theoretical discussion. Studies employing the CHANS framework tend to be more empirical than those employing SES, attempting to model, apply, or demonstrate the key concepts to an empirical case (e.g., McKey et al. 2010, Stevenson 2011, O'Connell and O'Donnell 2014). These studies are often conducted by disciplinarily diverse research teams that utilize the CHANS concept to connect and relate their research areas, as encouraged by Liu et al. (2007a). Although SES and CHANS developed in largely separate research communities, both emphasize the core value of jointly studying social and biophysical aspects of systems and their interactions (An and López-Carr 2012). We use the term SES/CHANS to refer to these shared characteristics.

POLICY AS A FEEDBACK MECHANISM IN SES/CHANS

Prior work in SES/CHANS has focused on terms such as resilience (Walker et al. 2004), robustness (Anderies et al. 2004), and adaptive capacity (Folke et al. 2002), suggesting that the role of policy should be to contribute to these components of SES/CHANS (e.g., Cumming et al. 2013). When incorporating policy into an SES/CHANS framework, Folke et al. (2002) recommend that policy should highlight relationships between the biosphere and societal development and should also allow for flexible and novel cooperation among stakeholders. In order to incorporate policy efforts into an adaptive management system, social-ecological feedbacks must be employed (Armitage et al. 2009). Incorporating policy can be challenging, as issues of power and culture are introduced that are not present when considering an ecosystem alone (Cote and Nightingale 2011).

Reactive N management may be an ideal system in which to examine social-ecological feedbacks (Stuart et al. 2012, 2015), and policy may be one such feedback mechanism (Olsson et al. 2004). However, the relationships between policy and agricultural N have not been examined in relation to concepts such as

adaptive management and adaptive governance. Evaluating the role of policy as a feedback in SES/CHANS will be a valuable means to gain understanding of reactive N management in the U.S.

NITROGEN USE IN AGRICULTURE

N is an essential nutrient and is often limiting in terrestrial ecosystems. In agricultural systems, crop demands often exceed supply of available N, and higher yields can be achieved by the addition of N from outside the system (Tilman et al. 2002). Some N can be added through the incorporation of N2-fixing plants in the crop rotation or as cover crops, though the supply generated by biological N fixation is not necessarily sufficient to replace what is removed with the harvested crop or lost from the environment (Robertson and Vitousek 2009). N supply is often supplemented by synthetic N, which makes up the sole outside source of N for 90 % of treated crop acres in the U.S. (Ribaudo et al. 2011). As a consequence of industrial fertilizer production, humans have approximately doubled the amount of reactive N applied to the land (Schlesinger 2009). Synthetic N can be applied in several forms such as liquid UAN, dry urea, and anhydrous ammonia gas (Ribaudo et al. 2011) and is responsible for the massive increase in grain yields that have been accomplished since the industrial revolution (Robertson and Vitousek 2009, Sinclair and Rufty 2012).

The challenge that synthetic N fertilizers present is that the majority of the applied N is not taken up by the crop or retained in the soil but is lost from the system (Robertson and Vitousek 2009, Ribaudo et al. 2011, Syswerda et al. 2012). Soluble forms of N, including nitrate (NO_3^-), ammonium (NH_4^+), and urea, are particularly prone to run off into waterways. Runoff from croplands makes up the largest single source of N inputs to surface waters in the U.S. from both point and nonpoint sources (Carpenter et al. 1998). Excess N in freshwater and coastal marine ecosystems leads to water quality impairments such as eutrophication, harmful algal blooms, and hypoxia (Carpenter et al. 2011, Howarth et al. 2011) that can damage ecosystem functioning and generate economic costs (Dodds et al. 2009, Smith and Schindler 2009).

EFFORTS TO MITIGATE NUTRIENT RUNOFF FROM AGRICULTLURE

Concern over the off-farm effects of nutrient loss in the U.S. have been of widespread concern since the 1970s (Drinkwater and Snapp 2007). State-led efforts to reduce both soil and nutrient loss have historically taken a voluntary approach with the dual purpose of benefitting farmers economically by conserving soil and nutrients on farm fields and concurrently reducing off-farm environmental impacts from agriculture (Drinkwater and Snapp 2007, Ribaudo 2015). These voluntary programs include the Conservation Reserve Program (CRP), which pays farmers to not farm sensitive land, and working-land programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP), which provide cost-sharing and resources for farmers with more specific management goals (Reimer and Prokopy 2014).

Several types of practices are promoted or supported by the CRP, EQIP, and CSP. Out-of-field practices function to intercept and possibly treat water that leaves farm fields so that nutrients carried out of the field do not immediately enter the surrounding ecosystem (Robertson and Vitousek 2009). These practices include the creation, conservation, and restoration of vegetative buffers and wetlands. The land used for vegetative buffers can often be enrolled in the CRP. In-field practices focus on improving N use efficiency by the method, timing, form, and rate of N applied, which can improve crop growth as well as reduce the potential for losses to the surrounding environment (Cassman et al. 2002, Galloway et al. 2008, Ribaudo et al. 2011). These practices include the use of stabilized and slow release product formulations, nitrification

inhibitors, sidedressing or split applications, N tests, precision applications, optical sensing, and crop production models (Robertson and Vitousek 2009; Weber and McCann 2015). Additional in-field practices include reducing or eliminating tillage and growing cover crops during the off-season, both of which serve to retain N in the soil for the next growing season (Drinkwater and Snapp 2007, Robertson and Vitousek 2009, Blesh and Drinkwater 2013, Robertson et al. 2014). Both the EQIP and CSP support the adoption of many of these in-field practices.

Despite the potential for these practices to improve crop yield and save farmers money by reducing fertilizer needs, the rates of adoption of these conservation or best management practices have been insufficient to produce desired water quality outcomes (Duff et al. 1992, Stonehouse 1996, Ribaudo 2015). Farmers' decisions about adopting conservation or best management practices for nutrients are based on several complex factors. These factors include (1) environmental attitudes (Reimer et al. 2012a), (2) concern over environmental quality on and off their farm (Reimer and Prokopy 2014), (3) economic factors such as crop prices and potential returns on investment from practice or equipment changes (Reimer and Prokopy 2014), (4) perceived effectiveness and benefits of the practices to the farm (Reimer et al. 2012b), (5) farm characteristics such as farm size and land ownership status (Reimer et al. 2013), and (6) the complication of applying for conservation programs (Reimer and Prokopy 2014).

REACTIVE NITROGEN ISSUES IN THE GULF OF MEXICO

Covering over 3,220,000 km2 and draining 31 states, the MRB is the largest watershed in the U.S. and the third largest in the world (Rabalais et al. 2010). This immense watershed is a valuable freshwater resource but also contains the nation's most productive farmlands. The upper reaches of the MRB, comprising the agriculture-intensive Corn Belt, contribute the highest inputs of nonpoint nutrient pollution relative to removal processes in the watershed (Burkhart and James 1999). Indeed, an estimated 52 % of N entering the Gulf of Mexico is derived from land planted with corn or soybeans, more than any other single source (Alexander et al. 2008). As a limiting nutrient for phytoplankton in the Gulf of Mexico, N stimulates primary production and subsequent consumption of oxygen through decomposition. The size of the hypoxic zone that ensues averages nearly 15,000 km2 each year and is associated with deleterious effects on fisheries (Rabalais and Turner 2012).

Agriculture in the MRB and hypoxia in the Gulf of Mexico are closely linked, and a large part of the solution lies in the reduction of nonpoint source pollution. If nutrient loads from nonpoint sources could be reduced by 20-30 %, the chlorophyll levels in the Gulf of Mexico would be reduced by 5-15 % and bottom water oxygen concentrations would increase 15-50 % (Hudson et al. 2005). This can be accomplished in part through expanded use of on- and off-field nutrient management practices already being promoted for the purposes of reducing N application and runoff (Ribaudo 2003, Hudson et al. 2005). However, as has been previously discussed, these practices are not employed by many farmers for a variety of reasons.

THE MISSISSIPPI RIVER/GULF OF MEXICO WATERSHED NUTRIENT REDUCTION TASK FORCE

The Mississipi River/Gulf of Mexico Watershed Nutrient Task Force (Nutrient Task Force hereafter) represents an attempted policy feedback in response to the increased extent of the hypoxic zone in the Gulf of Mexico. The Nutrient Task Force was established by a federal statute to coordinate over time a multi-tiered effort to reduce N and P loads from the MRB, which also includes the Atchafalaya River, to the Gulf of Mexico from both point and nonpoint sources. The goal in discussing this example is to (1) demonstrate how an existing policy can function or fail to function as a feedback in a SES/CHANS system and (2) examine the capacity for adaptive management and adaptive comanagement to be used within the existing U.S. political

system. We focus on the nonpoint source components of the Nutrient Task Force strategy, though point sources are a component of the strategy as well.

The MRB covers a very large area and includes numerous political units (e.g., states), none of which have jurisdiction over the Gulf of Mexico. Thus, the initial feedback necessary to manage hypoxia in the Gulf of Mexico is that which connects the problem in the Gulf to the federal government. This feedback was implemented through the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, which notes some of the social, economic, and environmental costs resulting from algal blooms and hypoxia around the country and the need to increase efforts to reduce them. The statute specified the establishment of an inter-agency task force for the purpose of assessing harmful algal blooms and hypoxia in the northern Gulf of Mexico and submitting a plan to Congress for reducing them. The statute specified that the plan was to include "incentive-based partnership approaches" (Harmful Algal Bloom Act 1998, section 604) and provided a small amount of funding to the National Oceanic and Atmospheric Administration (NOAA) for additional research and monitoring for the purposes of mitigating algal blooms and hypoxia.

Table 1. Principles of the Nutrient Task Force strategy to address hypoxia and harmful algal blooms in the Gulf of Mexico (Nutrient Task Force 2001).

Strategy
1. Encourage actions that are voluntary, practical, and cost-effective 2. Utilize existing programs, including existing State and Federal regulatory mechanisms 3. Follow adaptive management 4. Identify additional funding needs and sources during the annual Agency budget process 5. Provide measurable outcomes as outlined below in the three goals and strategies

The 2001 Nutrient Task Force Assessment and Action Plan to address hypoxia and harmful algal blooms in the northern Gulf of Mexico recognized two main approaches to addressing the problem: (1) reducing the amount of nitrogen entering the waterways in the MRB, and (2) improving nitrogen retention and denitrification within the MRB and in the coastal plains (Nutrient Task Force 2001). The strategy taken by the Nutrient Task Force was based on five principles (Table 1) and had three stated goals (Table 2). Of the five principles, two are of particular interest in this case: following adaptive management and providing measurable outcomes. The use of adaptive management is consistent with the call made by the resilience-oriented literature, and identifying and generating measurable outcomes is a key element of this approach (Berkes and Folke 1998). These principles (Table 1) have remained consistent over the evolution of the Action Plan. The coastal goal was revised in 2015 to extend the timeline on reducing the size of the hypoxic zone to the year 2035, while the others have remained un-changed (Nutrient Task Force 2015).

The 2008 Nutrient Task Force Action Plan evaluated the progress made by the 2001 Plan, examined new developments and scientific research, and laid out a new set of action items, which are largely revisions of action items from the 2001 Action Plan (Nutrient Task Force 2008). The 2013 Reassessment advised the continued implementation of the 2008 Action Plan (Nutrient Task Force 2013). The 2008 action items are divided into two categories: (1) actions to improve water quality through nutrient reduction and (2) actions to increase monitoring, improve scientific knowledge, and raise awareness. The focus of the water quality actions is the development and implementation of state-level nutrient reduction strategies, which are

described in the 2008 Action Plan as being a "road map" to nutrient loading reductions to the Gulf that can be tailored specifically for each state to account for the considerable variation that exists in "soils, hydrology, land use, and cropping practices as well as the legal, legislative, and administrative framework[s]" (Hypoxia Task Force 2008). It was recognized that states in the MRB, at the time of publication, had existing nutrient reduction strategies, but many strategies needed revisions to incorporate impacts on water quality issues in

Table 2. Goals of the Nutrient Task Force strategy to address hypoxia and harmful algal blooms in the Gulf of Mexico (Nutrient Task Force 2001).

Category	Goal
Coastal Gulf of Mexico	By the year 2015, subject to the availability of additional resources, reduce the 5-year running average areal extent of the hypoxic zone to less than 5,000 km2 through implementation of specific, practical, and cost-effective voluntary actions by all States, Tribes, and all categories of sources and removals within the Mississippi/Atchafalaya River Basin to reduce the annual discharge of nitrogen into the Gulf.
Within Basin	To restore and protect the waters of the 31 States and Tribal lands within the Mississippi/Atchafalaya River Basin through implementation of nutrient and sediment reduction actions to protect public health and aquatic life as well as reduce negative impacts of water pollution on the Gulf of Mexico.
Quality of Life	To improve the communities and economic conditions across the Mississippi/Atchafalaya River Basin, in particular the agriculture, fisheries, and recreation sectors, through improved public and private land management and a cooperative, incentive based approach.

the Gulf of Mexico in addition to local water quality issues (Hypoxia Task Force 2008). The state nutrient reduction strategies have been developed differently in the different states. The 2008 Action Plan did not provide much detail on what the state nutrient reduction strategies should include, but it did specify that adaptive management should be used so that strategies would be revised according to changing conditions and increased scientific knowledge. It also suggests that stakeholders should be involved in the development and implementation of the strategy. The 2013 Reassessment provides eight recommended elements for the state nutrient reduction strategies (Table 3; Nutrient Task Force 2013). These elements are generally present in state

Table 3. Nutrient Task Force recommendations for state nutrient strategies (Nutrient Task Force 2013).

Recommendation
1. Prioritize watersheds on a statewide basis for nitrogen and phosphorus loading reductions
2. Set watershed load reduction goals using best available information
3. Ensure effectiveness of point source permits
4. Control runoff from agricultural areas
5. Control point source pollution from municipal and industrial sources, stormwater runoff, and septic systems
6. Implement accountability and verification measures
7. Submit annual reports on implementation activities, biannual reports on load reductions and environmental impacts in targeted watersheds
8. Develop a work plan and schedule for numeric nutrient criteria development

Note: These eight recommendations come from a 2011 memo by N. K. Stoner, U.S. Environmental Protection Agency: Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions.

nutrient reduction strategies.

The Nutrient Task Force Action Plan calls for federal agencies to implement nutrient reduction strategies within existing programs and projects, considering independent actions that agencies can take and also actions that can facilitate state level actions and policies. These actions include mitigating nutrient loadings contributed by unrelated projects (e.g., Army Corps of Engineering projects that influence water

flow patterns), through increased funding for existing conservation programs that assist farmers in implementing practices that reduce nutrient loss or improve nutrient interceptions, and through interagency coordination. Federal and state agencies are also expected to identify strategies for existing programs with different but related goals to reduce nutrients to the Gulf of Mexico (e.g., modifying existing flood control projects and adjusting regulations intended to improve local drinking water quality). Additional action items within the Action Plan pertain to research and monitoring led by a range of federal agencies that ranges from examining nutrient and water quality dynamics in the MRB and the Gulf of Mexico, to evaluating the effectiveness of nutrient reducing practices, to analyzing and sharing data among stakeholders and agencies (Nutrient Task Force 2008, 2013).

ROLE OF POLICY AS A FEEDBACK

Figure 1 is a generalized representation of the multiple feedbacks involved in the creation of the Nutrient Task Force and the execution of its Action Plan. It shows how the effect of the hypoxic zone in the Gulf of Mexico, which was enhanced by human actions in the greater Mississippi River Basin (arrow 1), instigated the passage of the statute by Congress (arrow 2). This statute led to the creation of the Nutrient Task Force (arrow 3). The Nutrient Task Force assessed the situation, its causes and consequences, and produced its first Action Plan in 2001 (Nutrient Task Force 2001). State nutrient reduction strategies, a result of the implementation of the Action Plan (arrow 4), are expected in part to reduce sources of nutrient loss from agricultural activities by encouraging and supporting farmers to voluntarily adopt nutrient management practices on their farms (arrow 5). The federal government has had a recurring role in the system since the passage of the statute through federal agencies (i.e., EPA, NOAA, USGS, USDA,

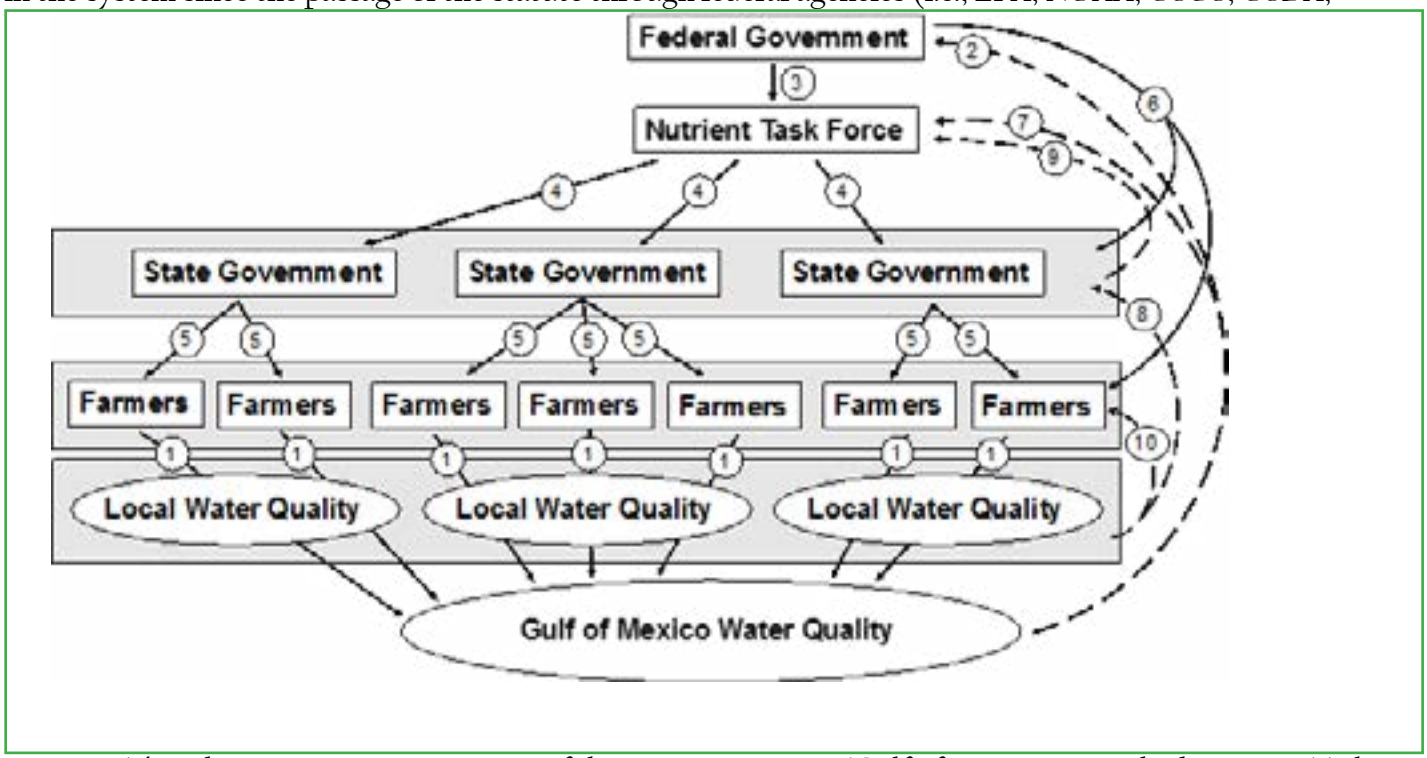


Figure 1. The adaptive governance system of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Nutrient Task Force). Policies associated with the Nutrient Task Force involve social components (boxes), biophysical components (ovals), actions (solid arrows), and feedbacks (dotted arrows).

Army Corps of Engineers) and its funding of specific activities, projects, and programs (arrow 6).
Since its establishment, the Nutrient Task Force has been working to improve scientific understanding of the drivers of Gulf of Mexico hypoxia as well as the practices that most effectively reduce nutrient loads to the Gulf. This information is used in the Action Plan assessments and reports and for revising the Action Plan over time as conditions and knowledge change (arrow 7). Similarly, local water quality (i.e., surface waters upstream of the Gulf of Mexico and contained within the jurisdiction of the state) influence state nutrient reduction strategies as states allocate their resources to priority watersheds and evaluate the effectiveness of their strategies (arrow 8). The effectiveness of state strategies also feeds back loosely to the Taskforce in its assessment of overall progress of goals for the Gulf of Mexico and monitoring of nutrient loads from the Basin sub-watersheds (arrow 9).
Given the high number of paths in the feedback loop, there are many potential places for the feedback to breakdown and fail to connect back to addressing the environmental problem of concern. For example, several funding-related actions in the 2001 Action Plan were not authorized by Congress, which resulted in less water quality and hypoxia monitoring than was anticipated. This lack of increased monitoring weakens the feedback between Gulf of Mexico water quality and the efforts of the Nutrient Task Force (arrow 7). Federal funding of relevant agency programs and state nutrient reduction efforts are always a potential source of weakness to their efforts to reduce nutrient loads to the Gulf of Mexico (arrow 6).

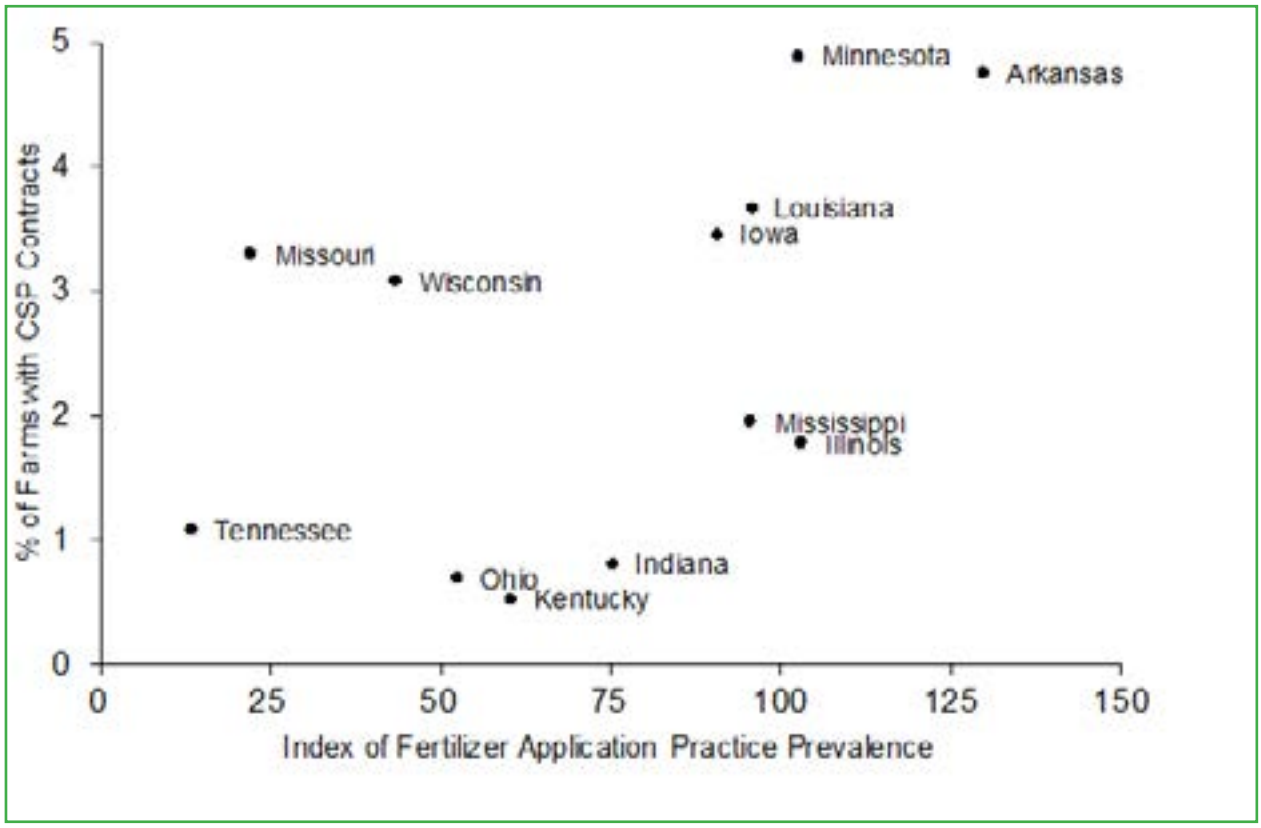


Figure 2. Index of relative prevalence of conservation-oriented fertilizer application practices in Conservation Stewardship Program (CSP) contracts in relation to the percentage of farms in the state with CSP contracts. The index was calculated by summing the number of contracts that included relevant practices, dividing by the number of CSP contracts in 2014, and then multiplying by 100. A contract may include multiple practices. Data were obtained from the Environmental Working Group (www.ewg.org) Conservation Database. Data originated with the Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA).

At an individual level, local water quality may provide a more effective feedback for farmers to reduce nutrient loss from their farms than water quality in the Gulf of Mexico, as local effects are perhaps more tangible than effects experienced thousands of miles away (arrow 10). However, if local water quality is high, farmers may not adopt conservation practices. Because nutrient conservation practices are all voluntary and incentive-based, low levels of farmer buy-in may result in ineffective implementation of state nutrient reduction strategies. There also seems to be variation among states in how actively the nutrient reduction strategy is being pursued. For example, it appears that while some states (e.g., Iowa, Arkansas) have completed their nutrient reduction strategies, other states (e.g., Kentucky, Tennessee) have not yet done so.

The variation among MRB states in farmer participation in USDA conservation and management programs, and the relative emphasis on N management, is a potential measure of efficacy in state management efforts. The prevalence of conservation-oriented fertilizer application practices (Figure 2), nutrient interception and retention practices (Figure 3), and nutrient management and conservation practices (Figure 4) vary widely in relation to the proportion of farms with CSP contracts among 13 core MRB states. Across the three indices,

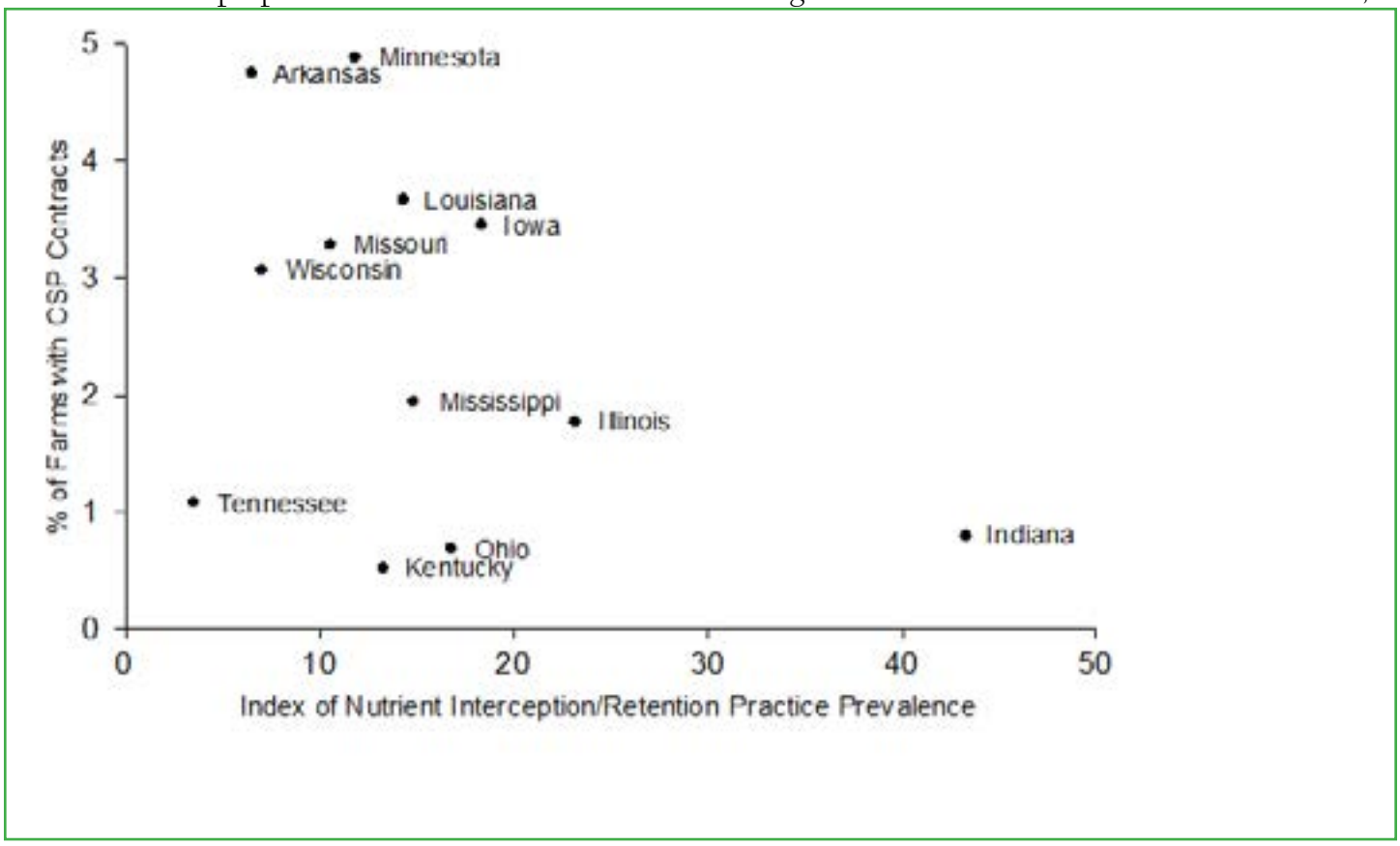


Figure 3. Index of relative prevalence of nutrient interception and retention practices in Conservation Stewardship Program (CSP) contracts in relation to the percentage of farms in the state with CSP contracts. The index was calculated by summing the number of contracts that included relevant practices, dividing by the number of CSP contracts in 2014, and then multiplying by 100. A contract may include multiple practices. Data were obtained from the Environmental Working Group (www.ewg.org) Conservation Database. Data originated with the Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA).

some states seem to have placed more emphasis on certain conservation practices than others. For example, Indiana is neither high nor low on the index of fertilizer application practices compared to the other states,

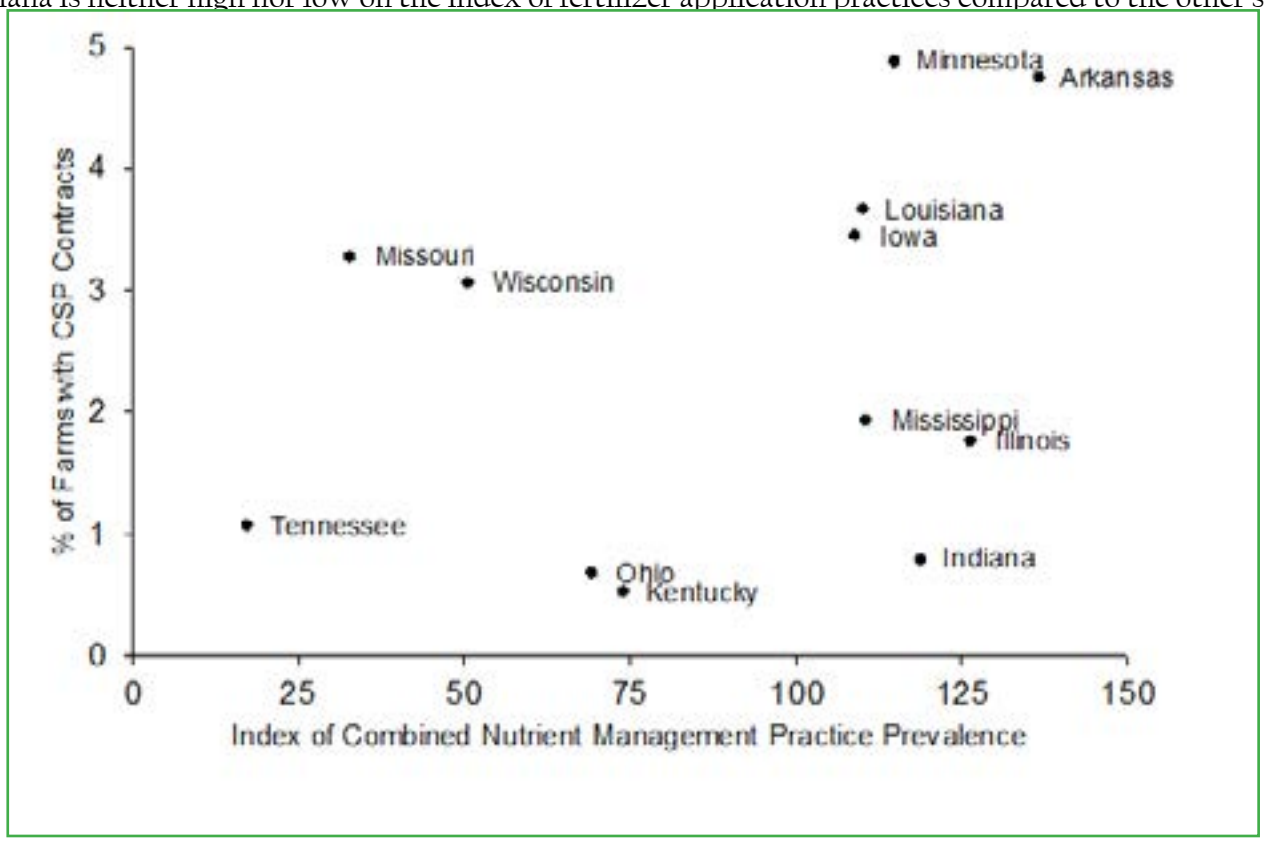


Figure 4. Index of relative prevalence of all nutrient management and conservation practices in Conservation Stewardship Program (CSP) contracts in relation to the percentage of farms in the state with CSP contracts. The index was calculated by summing the number of contracts that included relevant practices, dividing by the number of CSP contracts in 2014, and then multiplying by 100. A contract may include multiple practices. Data were obtained from the Environmental Working Group (www.ewg.org) Conservation Database. Data originated with the Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA).

but it is very high on the index of nutrient retention practices. Together, this puts Indiana in the top half of the 13 states for total nutrient management practices, but the state is comparatively low in the percentage of farmers who participate in the CSP. This analysis suggests that Arkansas and Minnesota have achieved the highest farmer participation in the CSP among the 13 states, and those farmers are likely to employ nutrient management practices when they do participate. Alternatively, Tennessee, Ohio and Kentucky have achieved the lowest degree of farmer participation in the CSP of the 13 states, and Tennessee also has the lowest index of nutrient conserving practice use among participating farmers. This example suggests varying degrees of success in policy implementation at the state level, with some states better encouraging farmers to participate in the program, and for nutrient related practices, than others.

DISCUSSION

The strategy instigated by the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 and created by the Nutrient Task Force not only explicitly employed adaptive management but is also an example

of adaptive comanagement and adaptive governance in action. The delegation to the individual states to create their own nutrient reduction strategies with limited requirements allowed states to include and utilize existing organizations, programs, and networks (Nutrient Task Force 2001). This flexibility resulted in strategies tailored to each state's context with the potential for greater buy-in from the institutions, agencies, and individuals who are necessary to implement the plan effectively.

The key aspect of the adaptive portion of adaptive management, comanagement, and governance is that it creates feedbacks (Berkes and Folke 1998). Feedbacks can exist even if people and their institutions do not recognize them, but adaptive management seeks and creates explicit feedbacks. The creation or presence of a policy may be a feedback (e.g., as a response to an environmental condition) but its effectiveness over time is highly determined by how adaptive it is. The U.S. government is made to adapt, but the pace of change is typically very slow. By the time an environmental condition is recognized as a problem, it has often reached critical levels (e.g., Stradling and Stradling 2008). Building adaptability into a law or strategy facilitates the speed at which feedbacks can take place, as it avoids the need to pass new laws to accomplish a goal that has already been identified. The management and governance associated with the Nutrient Task Force is an example of a functional implementation of an adaptive system, allowing for feedbacks at multiple organizational levels without fully relying on top-down policy adaptions (Figure 1).

The drawback to adaptive governance and comanagement especially is that it requires the cooperation of multiple individuals, agencies and organizations (Stringer et al 2006). If any key individuals or groups fail to cooperate with an enacted policy, either through active opposition or simply non-participation, progress toward goals can slow or stall and hinder the effectiveness of the effort. The risk of non-participation may be especially high when there are no enforcement mechanisms included in the larger strategy. The reason that individuals or groups may fail to cooperate in adaptive processes is likely based more on the social aspects of environmental problems rather than a disagreement over the biophysical realities (Berkes 2004, Carolan 2004). Environmental problems that are identified as such often have a strong socially constructed component; while biophysical conditions may not be new, it is only when society (or an influential portion of it) acknowledges a problem that action is taken, and actions can be strongly influenced by who perceives it to be a problem and what they believe the desired outcome should be (Taylor and Buttle 1992, Williams 1998). Uncooperative entities may not believe that the problem is as significant as is presented, that other problems are more important, or that the strategy being promoted will not be effective. The variation in state and farmer participation in conservation activities (Figure 2, 3, 4) demonstrates the potential drawbacks of an adaptive system wherein lack of participation may result in breakdown of policy feedbacks (Figure 1).

In conclusion, we have demonstrated how policy can act as a feedback in an SES/CHANS, especially if it includes an adaptive component. However, the method by which policy is implemented, even an adaptive policy, leaves plenty of room for the full feedback to be broken or its effect reduced. Reactive N management in the MRB and the Gulf of Mexico serves as an ideal example of the role of policy as a feedback in adaptive governance, particularly as variable participation of various states and individuals in management efforts demonstrates a gradient of success in employing policy feedbacks. Further examination of environmental policy associated with the Nutrient Task Force in a SES/CHANS approach may enable future improvements to the management of reactive N in the MRB.

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POLICY INSIGHTS

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