EPA
United States
Environmental Protection
Agency

National Center for Environmental Research
Science To Achieve Results (STAR) Research Program

2011

STAR Fellowship *Awardees* Research Portfolio

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Letter From the Director

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
RESEARCH AND DEVELOPMENT

Dear Research Partners:

Welcome to the community of scientists supported by the EPA.

As 2011 STAR Fellowship awardees, you are now members of a community that will produce the next generation of environmental leaders, thinkers and managers. Your individual research collectively will add to environmental research findings to advance the state of Environmental Science in the United States. The information, tools and techniques you develop will help find solutions to ever occurring environmental challenges across the globe.

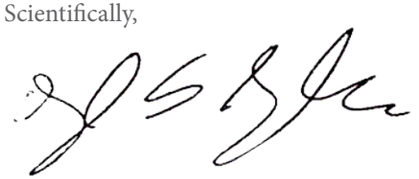
Addressing current and future environmental issues will require a coalition of scientists, engineers and policy makers in government, industry, academia and the nonprofit sector, all bolstered by a strong underpinning of environmentally related research and development nationwide. With the addition of a public made more aware of its relationship to the environment, the EPA is able to lead in building the components of an environmentally literate society and a functional environmental workforce.

The many topic areas that your research was selected under all fit within EPA's Office of Research and Development's main research platforms and complement much of EPA's internal science and engineering efforts.

This is where you fit as EPA STAR Graduate Fellows. You are at the nexus of becoming those transdisciplinary leaders who are and will be able to convert your academic and professional dreams into worthwhile scientific results that will have broad impact for the betterment of our environment and human health.

Again, welcome to a scientific journey and partnership that we at the EPA are excited about and hope you are as well.

Scientifically,



Christopher Zarba, Acting Director
National Center for Environmental Research

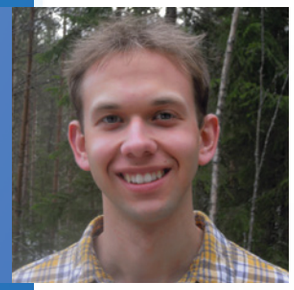
Clean Air

It's not just a fight for clean air, but a fight for everyone in this country to live in a personal environment in which he can live like a human being.

– Marylouise Oates, 1970

Clean Air

Clean Air
University of Delaware (DE)
E-mail: bbzdek@udel.edu
EPA Grant Number: FP917315
EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Atmospheric Chemistry



Bryan Richard Bzdek

Amines in Ambient Particle Formation and Growth

C

Bio

Bryan Bzdek earned his undergraduate degree at Bucknell University, where he majored in Chemistry and minored in French and Music. While at Bucknell, he performed research on clay minerals and received the Undergraduate Award in Environmental Chemistry. He is currently a doctoral student in Murray Johnston's group in the Department of Chemistry and Biochemistry at the University of Delaware, where he uses mass spectrometry to elucidate the mechanisms of atmospheric new particle formation.

Synopsis

The role of aerosols in global climate is poorly understood. New particle formation (NPF), whereby new particles form from gaseous species, may constitute 50 percent of global aerosol levels, but its mechanisms are not well characterized. This project aims to elucidate the roles of nitrogen-containing species in NPF. The results will improve our mechanistic understanding of the chemistry underlying NPF and will enable modelers to more accurately predict aerosol levels under varying conditions.

OBJECTIVE(S)/RESEARCH QUESTION(S)

A significant component of the global aerosol budget arises from new particle formation, whereby gaseous species condense to form new particles and then grow into the size range where they may affect global climate; however, the mechanisms for this process are poorly understood. This project aims to elucidate the roles of nitrogen-containing species on new particle formation so as to clarify mechanisms for particle formation in the atmosphere and enable modelers to better predict aerosol levels under varying conditions.

APPROACH

This project involves the application of mass spectrometry to study the composition and reactivity of small atmospherically relevant clusters and particles with amines and ammonia. One portion of this project involves use of Fourier transform ion cyclotron resonance mass spectrometry to examine the reactivity of small ammonium bisulfate clusters with various amines. Another portion involves using a flow tube apparatus coupled to a home-built aerosol mass spectrometer to examine the kinetics of amine exchange for ammonia and nanoparticle growth by amines and organic acids. The third portion of this project involves analysis of field measurements of ambient nanoaerosol composition to test predictions resulting from the laboratory measurements.

EXPECTED RESULTS

Results from experiments on small molecular clusters already indicate that amine-ammonia chemistry should be important and observable in small ambient clusters. Flow tube experiments will explore the hypothesis that amine-organic acid salts may be important contributors to nanoparticle growth in the atmosphere and explain the surprising presence of amines in nanoparticles arising from new particle formation. Finally, the field measurements will serve to test hypotheses arising from the laboratory measurements and to adjust understanding of the mechanisms underlying new particle formation.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

An improved understanding of the chemical mechanisms underlying new particle formation will have several benefits related to environmental and human health protection. First, the quantitative kinetics results will enable modelers to more accurately predict ambient aerosol levels under varying conditions, which will improve models of ambient cloud cover and ambient exposure in different environments. Second, the results of this project will indicate species that are significant to the formation and growth of ambient aerosol and will enable regulators to make informed decisions regarding regulation of relevant gas-phase species to reduce particulate matter levels.

Keywords: *aerosol kinetics, amine, new particle formation, nucleation*

Clean Air
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EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Chemistry ACS

Leah Dodson

C

Laboratory Studies of Tropospheric Air Pollution: Mechanism of Isoprene Oxidation

Bio

Leah Dodson received her undergraduate degree in Chemistry from Case Western Reserve University in 2010. During her tenure, she worked in a chemical physics laboratory with Dr. Carlos E. Crespo-Hernández, studying the fate of pharmaceuticals polluting drinking water sources. Leah is currently pursuing a Ph.D. in Physical Chemistry at the California Institute of Technology. She works with Dr. Mitchio Okumura to understand atmospheric chemistry and the fate of hydrocarbon emissions in the troposphere.

Synopsis

Hydrocarbons are oxidized in the atmosphere by free radical attack. The laboratory seeks to understand the chemical reactions that occur when radicals react with isoprene (the most prevalent non-methane hydrocarbon emission). These reactions are linked directly to the formation of ozone and the production of smog and other pollutants. The research conducted by the laboratory can provide mechanistic details about the reaction products of isoprene oxidation by NO_3, OH and Cl free radicals. These results are incorporated into models.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research will study the atmospheric fate of isoprene (the most prevalent non-methane hydrocarbon in the troposphere) in the presence of radicals such at OH, NO_3 and Cl. Alkenes are oxidized in the presence of both radicals and oxygen to form a peroxy radical, which undergoes a suite of reactions that impact air quality. This study seeks to understand how the branching of these reaction pathways can lead to gas phase products that go on to form ozone and various secondary organic aerosol products.

APPROACH

This study proposes to directly detect the peroxy radical intermediate in the gas phase using the high sensitivity analytical laser method, cavity ringdown spectroscopy (CRDS). CRDS is a spectroscopic method utilizing an optical cavity, a cell with two highly reflective mirrors (R > 99.9%) on each end, to substantially increase the effective pathlength (> km). Sensitivities of 10^{-6}~10^{-8} fractional absorption per pass are achieved, magnitudes higher than traditional absorption methods (10^{-4}). This project utilizes the fast response time, high sensitivity and large scanning range of CRDS to directly detect the peroxy radical intermediate.

EXPECTED RESULTS

Direct spectroscopic detection of the isoprene peroxy radical intermediate will enable the measure of the kinetics of the peroxy radical reaction pathways. The data gained from this project will be used in atmospheric models to provide better predictions for air quality control and air pollutant regulation.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research is critical to understanding the fate of volatile organic compounds in the troposphere, particularly of isoprene. This knowledge will help to understand the formation of oxidized species and their contribution to secondary organic aerosol formation. Once a more accurate picture of the fate of isoprene and other alkenes is had, researchers can work with modelers to provide lawmakers with more information on the precursors, both anthropogenic and biogenic, of smog and aerosols that are a severe detriment to human health.

Keywords: *isoprene, radical, nitrate, hydroxyl radical, chlorine radical, peroxy radical, oxidation, spectroscopy, air quality, atmospheric sciences, chemistry and physics, measurement, emissions standards, pollution, air, alkenes, air quality data, air pollution models, hydrocarbon oxidation*

Clean Air
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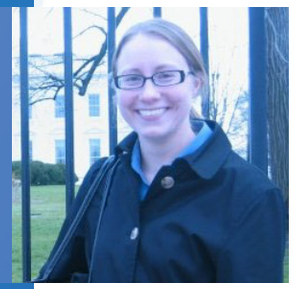
EPA Grant Number: FP917301
EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Chemistry ACS



Jennifer Liljegren

C

Experimental Investigation of Radical Propagation Pathways in the OH-Initiated Oxidation of Isoprene Under NO_x-Free Conditions

Bio

Jennifer Liljegren earned her B.S. in Environmental Studies with a minor in Chemistry from the University of Kansas. After graduating, she taught 8th grade Math in Texas via Teach for America. She then earned her Master's of Public Affairs (M.P.A.) and Master's of Science in Environmental Science (MSES) from the School of Public and Environmental Affairs (SPEA) at Indiana University (IU). She is currently in the Ph.D. Program in Environmental Science at IU, where she studies atmospheric processes such as the chemistry of ground-level ozone.

Synopsis

The hydroxyl (OH) radical-initiated oxidation of volatile organic compounds (VOCs) leads to the production of ozone and secondary organic aerosols (SOA), the primary components of photochemical smog. Isoprene, a VOC emitted by vegetation, contributes about one-third of the combined natural and anthropogenic sources of VOCs worldwide. This project will investigate whether the OH-initiated oxidation of isoprene maintains, rather than diminishes, the oxidizing capacity of the atmosphere.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Hydroxyl (OH) radicals play a central role in the chemistry of the atmosphere. In addition to controlling the atmospheric lifetime of greenhouse gases such as methane and the alternative chlorofluorocarbons that are important to issues of global climate change, the OH-initiated oxidation of volatile organic compounds (VOCs) leads to the production of ozone and secondary organic aerosols (SOA), the primary components of photochemical smog. Isoprene, a VOC emitted by vegetation, contributes about one third of the combined natural and anthropogenic sources of VOCs worldwide. Recent measurements of OH radicals in forest environments show serious discrepancies with modeled concentrations, suggesting that the current understanding of OH + isoprene chemistry is incomplete. This project will investigate the OH-initiated oxidation of isoprene and directly test whether reaction pathways therein maintain, rather than diminish, the oxidizing capacity of the atmosphere.

APPROACH

Experiments will use a turbulent flow tube reactor operating at atmospheric pressure and room temperature. Hydroxyl radicals will be generated in the reactor by UV photolysis of hydrogen peroxide, and isoprene will be introduced to react with the OH radicals. Any OH radicals produced under the conditions of the experiment will be measured using laser-induced fluorescence (LIF) in a low pressure sampling cell based on the Fluorescence Assay by Gas Expansion (FAGE) technique.

EXPECTED RESULTS

It has been suggested based on theoretical studies that isomerization reactions in the isoprene oxidation mechanism produce OH radicals. The yield of OH radicals from the isoprene oxidation mechanism will be measured directly under a variety of experimental conditions. The measured yields will be compared to theoretical predictions and used to model ambient OH concentrations to see if the experimental measurements improve the discrepancies with current atmospheric chemistry models.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Improving the understanding of the impact of biogenic emissions such as isoprene on the chemistry of ozone and SOA production in the atmosphere has important implications for regional air quality control strategies in areas with high isoprene emissions, such as the eastern United States. Because isoprene emissions are so globally abundant, it also is important to investigate how changes in isoprene emissions as a result of global climate change may affect ambient OH concentrations and thus the oxidizing capacity of the atmosphere in the future. Therefore, in addition to improving the scientific understanding of the chemistry of tropospheric ozone and SOA production, the broader environmental applications of this work include an improved ability to predict how changes in isoprene emissions arising from factors such as land use changes, forest succession and climate change affect the composition of the atmosphere and the OH radical concentrations necessary for greenhouse gas removal.

Keywords: *VOCs, isoprene, NO_x, OH radicals, ground-level ozone, SOA, climate change, greenhouse gases, atmospheric chemistry*

Clean Air
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EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Chemistry ACS

Amanda S. Priest

C

Source-Specific Molecular Signatures for Light-Absorbing Carbonaceous Aerosols

Bio

Amanda Priest received her undergraduate degree in Biochemistry from Old Dominion University (ODU) in 2006. She entered ODU's graduate program in Chemistry in 2007. As she completed her M.S. in Chemistry in 2010, she was selected as a Departmental Ciba scholar to begin her work towards a Ph.D. in Chemistry at ODU in summer 2010. Her doctoral research will focus on the relationships between light-absorbing properties and molecular structure for atmospheric particulate matter from natural and anthropogenic emission sources.

Synopsis

In the past 250 years, emissions due to human activities have significantly altered air quality, negatively impacting human health and playing a major role in global warming. Light-absorbing aerosols are released into the atmosphere from natural and anthropogenic sources, contributing to the warming effect. This project will use advanced analytical instruments to evaluate the nature and origin of light-absorbing carbon in aerosols, and establish relationships specific to key emission sources.

OBJECTIVE(S)/RESEARCH QUESTION(S)

There is strong evidence that suggests emissions resulting from industrialized society (industrial and transportation-related emissions) have played a key role in changing the chemical composition of the atmosphere, resulting in a net global warming. Theory suggests that the chemical composition of organic aerosols will determine their radiative effect; however, there is no unambiguous chemical definition for organic aerosol light-absorbing components, including black carbon and brown carbon. This project will focus on the chemical characterization of light-absorbing components in organic aerosols from various emission sources and will seek to identify the sources that make the largest contribution to atmospheric aerosols from these contaminants.

APPROACH

Ambient aerosol samples will be collected from key natural and anthropogenic emission sources, including an industrial region, a high traffic area, a biomass burning event and a rural background site. Samples from each site will be evaluated using a combination of ultraviolet visible spectroscopy and Fourier transform ion cyclotron resonance mass spectrometry. These techniques will allow for the determination of light-absorbing character and molecular composition for the collected samples, and the data will be used to establish the relationship between degree of aromaticity and light-absorption. Finally, multivariate statistical analysis will be employed to determine source-specific molecular components.

EXPECTED RESULTS

A direct correlation of light absorption is expected to be found with several mass spectrometric measurements, including degree of aromaticity, the types and abundances of condensed aromatic compounds and specific combustion-derived chemical markers. Such important relationships have always been considered to exist intuitively, but have not been explicitly demonstrated. Emission sources having large contributions from combustion-derived material, such as fossil fuel emissions, are expected to have the most aromatic character, thus absorbing the most light. Using the chemical information obtained from ultrahigh resolution mass spectral analysis, multivariate statistical analysis can reveal relationships between the various aerosol emission sources.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Determining the specific relationship between light-absorbing character and chemical signatures will provide a more comprehensive accounting for light-absorbing carbonaceous aerosols and will help to pinpoint the emission sources that have the most detrimental effect on the Earth's radiative budget. This information will reduce uncertainties related to current climate modeling schemes and allow policy-makers to implement more effective mitigation strategies to target problem pollutants from abundant sources.

Keywords: *light-absorbing carbon, black carbon, brown carbon, organic aerosols, atmospheric particulate matter, FT-ICR MS, climate change, anthropogenic effects, atmospheric chemistry*

Clean Air
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EPA Grant Number: FP917370
EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering/Air quality Monitoring

Alexander Torres-Negron

C

Development of Methods for Measuring Carbon Particles in Precipitation and Determination of Wet Removal Rates

Bio

Alexander Torres-Negron holds a B.S. in Civil Engineering (2003) and an M.S. in Environmental Engineering and Water Resources (2008) from the University of Puerto Rico at Mayaguez. In 2008, he obtained the GAANN Fellowship and began the Ph.D. program in Environmental Engineering and Science at the University of Illinois at Urbana-Champaign. His research interest is the influence of air pollution on water resources. He currently is researching the wet deposition of carbon aerosols to assess their atmospheric lifetime.

Synopsis

Fuel combustion and other activities produce carbon aerosols that are transported in the atmosphere and have adverse effects on visibility, climate change and human health. These effects depend on the residence time of carbon aerosols in the atmosphere, which is controlled by wet deposition. This research is developing an analytical method to measure organic and black carbon in rain. The concentration of carbon in rain will be monitored at field sites to determine the wet removal rates.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Current understanding of the atmospheric cycle of carbon aerosols is poorly understood still because their removal rate by wet deposition has not been studied meticulously. This research project will measure the concentrations of organic and black carbon in precipitation, and match them with their respective atmospheric concentrations at a specific site, yielding insight into aerosol removal from the atmosphere. This study also will provide a record of carbon particle concentration in precipitation at multiple sites that can be used to evaluate the removal predictions by atmospheric models. This database will be an important contribution to the scientific community for the accurate determination of the effects of carbonaceous aerosols on human health, visibility and climate change.

APPROACH

The first stage of this research is to develop an analytical method for measuring organic carbon and black carbon in precipitation. The TOC Analyzer will be used to measure dissolved organic carbon, and the OC/EC Analyzer (Thermal-Optical Analysis) will be used to measure particulate organic carbon and black carbon. Laboratory standards made from carbon aerosols generated in the laboratory will be used to evaluate the efficiency of the analytical method. In the second stage of the research, the developed method will be used to measure the concentration of carbon particles in precipitation. Rain samples will be collected during one year in the Bondville Environmental and Atmospheric Research Station at Bondville, Illinois. The concentrations of carbon particles in rainwater will be matched with the concentration of carbon aerosols in the atmosphere, measured by the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program. Precipitation sampling will be extended to some other monitoring stations within the National Atmospheric Deposition Program (NADP) to increase the spatial distribution of the measurements. The database of carbon aerosol concentration in rain will be used to determine the scavenging coefficients of the individual species of carbon aerosols. In addition, back trajectory modeling will be used to determine the dominant sources of carbon aerosols in the region.

EXPECTED RESULTS

At the end of this research, it is expected to define and recommend an analytical procedure for measuring carbon in rainwater that can be used with confidence by other researchers. A dataset of carbon particle concentration in rain, matched with atmospheric concentrations, will be created. Carbon concentration in rain also will be correlated with major ions and elements in rain, helping to understand the principles that lead the removal by wet deposition. The inclusion of multiple monitoring sites will aid to evaluate the removal rates at different regions and times. This area and time distribution of concentration will help to identify the major sources and distances that carbon particles are transported before being removed from the atmosphere by wet deposition.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research project will yield insight into the removal rate of carbonaceous aerosols from the atmosphere by precipitation, and will identify the processes that affect the wet scavenging. This information is necessary to improve the fidelity of models used to assess the impacts of carbonaceous aerosols on human health, visibility and climate change.

Keywords: *wet deposition, wet scavenging, organic carbon, black carbon, elemental carbon, air quality, climate change, air pollution, atmosphere, precipitation, rain*

Clean Air
University of Washington (WA)
E-mail: mzatko@uw.edu
EPA Grant Number: FP917302
EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Atmospheric Chemistry

Maria Christine Zatko

C

Investigating the Impact of Snowpack Photodenitrification on Polar Atmospheric Chemistry Utilizing Results From a Snowpack Radiative Transfer Model in GEOS-Chem

Bio

Maria Zatko received her undergraduate degree in Meteorology from the Pennsylvania State University in 2009. Maria was an intern at the Mount Washington Observatory in 2007 and was awarded a NOAA Hollings Scholarship, which allowed her to intern at the NOAA Pacific Marine Environmental Laboratory in 2008. She is interested in various aspects of atmospheric chemistry and is currently studying the photolysis of nitrate in polar snowpacks. Maria is actively involved in the American Meteorological Society and the University of Washington Atmospheric Science Outreach Club.

Synopsis

The photolysis of nitrate in the snowpack alters the preservation of nitrate in ice cores and is a source of oxidants (NO_x, OH) to the atmosphere. These oxidants control the lifetime of trace gases (CO, CH_4) and may be linked to ozone production above the snowpack. This project analyzes the physical and chemical processes influencing the flux of NO_x from the snowpack. Results are incorporated into a global chemical transport model to quantify the nitrogen and oxidant budgets in polar regions.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The NO_x produced through snowpack photodenitrification increases the atmospheric oxidative capacity above the snowpack. The preservation of photochemically active species, such as nitrate, is altered in ice cores when NO_x is converted to nitric acid in the atmosphere and deposited back to the snowpack. This study will implement a process based representation of snowpack photodenitrification in polar regions in a global chemical transport model utilizing a parameterization for actinic flux in snowpack to investigate how photodenitrification redistributes nitrate across Antarctica and Greenland.

APPROACH

This study will use a snowpack radiative transfer model (Grenfell, 1991) with updated optical properties in the UV wavelength region (Warren and Brandt, 2008) to develop a simple and broadly applicable parameterization for vertical profiles of actinic flux in snowpack. The e-folding depth of actinic flux in snowpack is two to eight times higher than previously calculated. Photolysis is occurring at deeper depths in the snowpack than previously assumed and it is therefore necessary to evaluate the assumption that all photo-produced NO_x will escape from the snowpack to the atmosphere. This study will evaluate this assumption by comparing the lifetime of NO_x against escape processes, such as diffusion and wind pumping, to the chemical lifetime of NO_x, such as conversion to nitric acid, in the snowpack. The depth below which the photo-produced NO_x will not escape into the atmosphere is called the ventilation depth. This study will compute a range of NO_x fluxes based on variations in ventilation depths and nitrate concentrations from snowpacks in Antarctica at South Pole, Halley and Neumayer and in Greenland at Summit. The next step is to incorporate the snowpack actinic flux parameterization and the ventilation depth methodology into a global chemical transport model (GEOS-Chem).

EXPECTED RESULTS

The updated optical properties of ice in the UV wavelength region lead to larger e-folding depths of actinic flux in snowpack than previously calculated in Antarctica (30 cm) and Greenland (15 cm). The study finds that the e-folding depth of actinic flux in the snowpack is most dependent on soot and dust concentrations, effective snow grain radius and solar zenith angle. Because photodenitrification is occurring at deeper depths in the snowpack, the study finds that it is necessary to consider the escape processes and chemical processes influencing the lifetime of NO_x in the snowpack because not all the NO_x produced through snowpack photodenitrification can escape to the atmosphere. Because the ventilation depth is strongly dependent on sastrugi dimensions, wind speed and halogen (BrO, IO) concentrations, it is necessary to accurately determine the vertical profile of halogen concentrations in snowpack interstitial air. Although there are large uncertainties in the ventilation depth and a wide range of observed nitrate concentrations at South Pole, Halley, Neumayer and Summit, the computed NO_x fluxes agree well with observations at these polar locations.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The release of NO_x and OH from snowpacks influence the lifetimes of trace gases such as carbon monoxide, methane and mercury in the overlying atmosphere. Enhanced boundary layer ozone concentrations have been observed in at least one region of elevated photo-produced NO_x (South Pole), and it is possible that snowpack photodenitrification is related to the high ozone concentrations recently reported in Wyoming. Gaining a better understanding of snowpack photodenitrification and its influence on the global nitrogen and oxidant budgets will help determine if snowpacks are linked to the production of ozone and other pollutants in the atmosphere.

Keywords: *photodenitrification, photochemistry, snowpack, nitrate, NO_x, snowpack actinic flux, GEOS-Chem, Antarctica, Greenland*

Drinking Water

Water flows from high in the mountains
Water runs deep in the Earth
Miraculously, water comes to us,
And sustains all life.

– Thich Nhat Hanh, Buddhist monk

Drinking Water

Drinking Water
University of Nevada (NV)
E-mail: bowdenk2@gmail.com
EPA Grant Number: FP917304
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2013
Project Amount: $84,000
Environmental Discipline: Civil/Environmental Engineering

Katie Sue Bowden

D

The Osmotic Membrane Bioreactor for the Protection of Human Health and the Environment

Bio

Katie Bowden received her B.S. in Civil and Environmental Engineering from the University of Nevada, Reno (UNR) in spring 2010. She began her M.S. program at UNR in fall 2010 on a Nevada NASA Space Grant Consortium Fellowship. At that time, Katie began studying the osmotic membrane bioreactor (OMBR) system for potable treatment of wastewater in space. Her current research focuses on terrestrial applications of the OMBR system.

Synopsis

The OMBR system represents a unique and innovative combination of forward osmosis (FO) and MBR technologies to enhance the quality of wastewater effluent for potable reuse applications and for discharge to the natural environment. This system utilizes a submerged FO membrane in a bioreactor. Through osmosis, water diffuses from the bioreactor, across a semi-permeable membrane, and into the draw solution, a high concentration solution with high osmotic pressure. The FO membrane acts as a barrier to solute transport and provides high rejection of the contaminants in the wastewater stream. The diluted draw solution is sent to a reconcentration process (e.g., reverse osmosis or membrane distillation), which reconcentrates the draw solution and generates a high-quality product water. The main objective of the proposed research is to quantify the technical and economic feasibility of the osmotic membrane bioreactor system to produce high-quality product water suitable for potable reuse.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The OMBR system represents a unique and innovative combination of forward osmosis (FO) and MBR technologies to enhance the quality of wastewater effluent for potable reuse applications and for discharge to the natural environment. This system utilizes a submerged FO membrane in a bioreactor. Through osmosis, water diffuses from the bioreactor, across a semi-permeable membrane and into the draw solution, a high concentration solution with high osmotic pressure. The FO membrane acts as a barrier to solute transport and provides high rejection of the contaminants in the wastewater stream. The diluted draw solution is sent to a reconcentration process (e.g., reverse osmosis or membrane distillation), which reconcentrates the draw solution and generates a high-quality product water. The main objective of the proposed research is to quantify the technical and economic feasibility of the osmotic membrane bioreactor (OMBR) system to produce high quality product water suitable for potable reuse.

APPROACH

The first step is to perform a bench-scale study to evaluate the efficacy of the draw solution in withdrawing water from the bioreactor and not adversely affecting biological treatment. Different inorganic and organic draw solutions will be tested using an FO setup to determine which solutions will be ideal for the OMBR system. Then, design and construction of a long-term laboratory-scale OMBR system and its subsystems will be completed. All systems will be operated in alternating aerobic and anoxic modes in a single reactor. Existing reverse osmosis and membrane distillation subsystems will be modified to be used in conjunction with the FO and bioreactor subsystem as a final treatment step to reconcentrate the draw solution and achieve potable drinking water. The biomass will be collected from a conventional wastewater treatment facility to obtain biomass already acclimated to municipal wastewater. The final product water will be analyzed for the traditional organics, solids and nutrients, as well as for emerging trace organic compounds.

EXPECTED RESULTS

A laboratory-scale OMBR system (OMBR followed by RO) designed in the PI's laboratory has undergone preliminary investigation. It was found that the dual osmotic barrier system demonstrated high sustainable flux and removed 99 percent of organic carbon and 98 percent of ammonia-nitrogen from domestic wastewater influent, respectively. The semi-permeable FO membrane has been shown to reject 98 percent of DOC due to its non-porous composition, enhancing removal efficiencies that can be achieved by microporous membranes used in MBRs. These results indicate the potential for high-performing OMBR systems, especially with optimization measures that will be taken in this study with regards to draw solution and FO membrane selection. In the OMBR system, the lack of hydraulic pressure across the membrane reduces compression of the chemical or particulate foulant layer on the membrane surface, reducing fouling on the membrane and enhancing water flux. Because the flux of the OMBR system can likely be maintained by optimizing hydrodynamic operating conditions or using osmotic backwashing only, it is expected that the FO process will require no chemicals for backwashing, making the process more environmentally friendly. Optimal use of draw solutions also will enhance FO performance, maximizing water flux while minimizing reverse salt transport into the bioreactor.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

More stringent regulations and the potential to produce high-quality effluent make OMBRs an attractive process for domestic wastewater treatment. Substantially reduced costs associated with membrane fouling, membrane backwashing and cleaning, membrane replacement, and chemical consumption and disposal are expected. Consideration of these reduced costs along with the substantially improved removal of both traditional and emerging pollutants give the novel OMBR system great potential for human health and environmental protection.

Keywords: *osmotic membrane bioreactor, potable water reuse, forward osmosis, membrane bioreactor, draw solution*

Drinking Water
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EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental & Water Science

Laura Renee Brunson

D

Sustainable Technologies for Fluoride Removal From Drinking Water for Rural Communities in Developing Regions

Bio

Laura Brunson is a Ph.D. student in the College of Engineering at the University of Oklahoma (OU). Laura received a business degree in 2002 and, as a National Science Foundation Graduate Fellow, earned a Master's degree in Environmental Science in 2009 from OU. Her research focuses on technologies and implementation methods for fluoride and arsenic removal from drinking water in emerging regions. She is currently working on a drinking water research project in the Rift Valley of Ethiopia and serves as an adjunct lecturer, teaching Social Entrepreneurship, in the College of Business.

Synopsis

Fluoride and arsenic are major contributors to the world drinking water crisis, affecting approximately 200 and 100 million people, respectively. Consumption of elevated levels of these can result in significant health and financial issues. This work focuses on developing and testing innovative technologies (e.g., aluminum-coated bone and wood chars) for removing fluoride and/or arsenic from drinking water, and on best practices for implementation in rural emerging communities.

OBJECTIVE(S)/RESEARCH QUESTION(S)

A major global issue is that approximately 884 million people around the world lack access to safe drinking water supplies. The health issues resulting from inadequate safe drinking water contribute to other world concerns such as education, maternal health and economic development. Fluoride and arsenic are significant contributors to the world drinking water crisis, affecting approximately 200 and 100 million people, respectively. Consumption of elevated levels of fluoride and arsenic can result in serious health and financial issues. To increase access to safe drinking water, sustainable, inexpensive and locally available materials must be developed, assessed and improved. This work focuses on developing and testing innovative technologies (e.g., aluminum coated bone and wood chars) for removing fluoride and/or arsenic from drinking water, and on assessing best practices for implementation in rural emerging communities.

APPROACH

The goal of this research is to develop, characterize and evaluate the effectiveness and sustainability of novel materials for fluoride and arsenic removal in emerging regions of the world. These materials will be developed using principles of colloid and surface chemistry to amend carbon-based materials to enhance the adsorption and sustainability of these materials using surface modification methods. These methods will entail coating the high surface area char materials with an appropriate metal or metal mixture and testing pre-treatment and surface modification techniques. Materials will be tested under various conditions (e.g., with competing ions, at different pH values and varying the solid-liquid ratio) using batch adsorption tests and continuous flow column studies. The most effective materials then will be tested for environmental impact by conducting a life cycle assessment (LCA). The best selections from the LCA will undergo a test implementation study in a rural village in Ethiopia with the end goal being to produce successful fluoride removal media and water treatment implementation guidelines useful for researchers/implementers in the United States and abroad.

EXPECTED RESULTS

The approach of this research is helpful because it will produce many tangible outcomes. One helpful product is the technical data that will be discovered through the process of testing different media coating and treating methods. This data could have applications even beyond the field of drinking water treatment. A second helpful outcome will be the sustainable and useful media produced as the result of this study. This media has the potential to be produced and used in many countries around the world to remove fluoride, and possibly arsenic, from water to produce safe drinking water. This product result also has the potential to be part of a U.S.- or developing country-based social entrepreneurial organization that would get safe drinking water into communities and also contribute to local economic development. The inclusion of the life cycle assessment and implementation study components of this work complements the technical aspects and allows for a larger contribution towards increasing access to safe drinking water by finishing the cycle from engineering technology research to successful implementation in communities of need.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The overarching goal of this research is to develop and assess novel technologies that will treat water to make it safe for human consumption. Getting people around the world access to safe drinking water would avoid numerous health difficulties and save millions of dollars in health expenses and lost productivity each year. Additionally, although the primary focus of this work is on researching and assessing a successful and acceptable water treatment technology, the research includes a LCA component. This LCA will compare the environmental impacts of several valid treatment technologies for different regions to determine the water treatment media with the least harmful environmental impact. Therefore, this work is intended to contribute to solving the global drinking water crisis in a way that minimizes the potential for negative environmental impacts.

Keywords: *fluoride, drinking water, bone char, wood char, aluminum coating*

Drinking Water
The Johns Hopkins University (MD)
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EPA Grant Number: FP917359
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Civil/Environmental Engineering

Sara A. Piaskowy

D

Contamination Risk Assessment for Hurricane Damaged Water Distribution Systems

Bio

Sara Piaskowy completed her undergraduate degree in Civil and Environmental Engineering from Princeton University in 2007. Following graduation, Sara spent a year in Burkina Faso, West Africa at 2iE where she researched point-of-use water treatments and established a long-term collaboration between Princeton and 2iE. In 2010, Sara graduated from Stanford University with a Master's degree in Environmental Engineering with a focus on water and developing countries. Sara is currently pursuing a Ph.D. at Johns Hopkins University, focusing on the intersection of water systems, disasters and public health.

Synopsis

This research will investigate changes in distribution system water quality caused by pipe breaks and drops in water pressure that result from hurricane damages, as well as normal system aging. Historical data of hurricane damages will be used to create a damage model, lab simulation and field data collection will be used to study changes in water quality, and a simulation-based risk model will be developed to assess contamination potential from damages to water systems from hurricanes.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The objective of this project is to understand and model the risk of exposure to contamination from intrusion events caused by hurricane damages. This risk assessment then will be applied to evaluate policy intervention alternatives for reducing exposure to contamination.

APPROACH

Achieving the goals of the research requires a three-prong approach. The first approach is to develop a model for predicting hurricane damages to water distribution systems. This will be done through analysis of historical hurricane records. Second is to study the volume of contamination intrusion due to pressure transient events. This will be done with controlled laboratory experiments and the results of which will be used to create a field-based data collection experiment to document intrusion in a real system. The final approach will be to develop a simulation-based contamination risk model for a hurricane damaged water system. This risk model will incorporate the results from the experimental phase, running simulations under various scenarios to observe differences in contamination risk.

EXPECTED RESULTS

This work expects to find patterns of water system damages resulting from hurricanes that can be explained by characteristics of the water system or characteristics of the hurricane. At present, knowledge of water system damages from hurricanes is locally held. This work will likely find similarities across experiences and seek to determine the most important forces when considering water system performance in hurricanes. This work also expects to find that during a pressure transient, depending on the duration and intensity of pressure drop, there will be a detectable increase in turbidity and decrease in chlorine residual. Finally, with respect to risk assessment this study expects to find that greater and more frequent pressure transients will result in greater contaminant intrusion and increased threat to public health.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This work has the potential to fill a key knowledge gap. At present, there is evidence that pressure transients occur regularly in a water system and that during a pressure transient intrusion of surrounding soil occurs. The missing point here is to understand to what degree is water quality affected by a pressure transient intrusion. If water quality is shown to degrade significantly as a result of a transient, policies could be put in place to reduce the occurrence of pressure changes or notify affected households and suggest they buy bottled water or boil water during the time when the pressure change might occur. Understanding the contamination effect of pressure transients could help develop new practices that will be more protective of water quality during the distribution phase.

Keywords: *hurricanes, water system(s), intrusion, pressure transient, simulation, risk*

Drinking Water
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Thomas L. Zearley

D

Degradation of Trace Organic Pollutants in Drinking Water Biologically Active Filters

Bio

Tom Zearley received his Bachelor's degree in Biosystems and Agricultural Engineering from the University of Minnesota-Twin Cities. Afterwards, he was an intern for the U.S. House of Representatives-Agriculture Committee for a half year. He then started a Ph.D. program in Environmental Engineering with an Engineering for Developing Communities emphasis, at the University of Colorado at Boulder. He also has traveled to Nepal and worked with a rural village on water and sanitation projects.

Synopsis

Trace concentrations of pollutants in drinking water supplies such as pharmaceuticals and pesticides can be removed by biological filtration. Biological filtration can provide an environmentally friendly alternative to more costly treatments. Removal of 35 pollutants in biological filters will be assessed, and optimal design and operation parameters will be determined. The final product will be a "treatment technique" for application in future regulations.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research will investigate and model the effects of biological filter design and behavior on trace micropollutant biodegradation by attached microorganisms under drinking water conditions. In addition, biofiltration can be cast into the regulatory framework by viewing it as a "treatment technique" for the control of biodegradable micropollutants.

APPROACH

Biological filter design will be investigated by determining the role of contact time with active biomass, impacts of ozonation, and filter media on micropollutant biodegradation. Biological filter behavior will be characterized by determining the retained biodegradation capacity of attached biomass after absences of exposure and the ability of nitrifying organisms to biodegrade different types of micropollutants. Micropollutants were selected based on environmental occurrence and represent a wide range of biodegradation potential. The micropollutants consist of 35 pharmaceuticals, pesticides, personal care products and endocrine disrupting compounds with concentrations ranging from 10 to 500 ng/L. Incorporating results on filter design and behavior along chemical characteristics, a "treatment technique" will be developed.

EXPECTED RESULTS

It is expected that the majority of micropollutants will be biodegradable to varying degrees with short acclimation periods for most micropollutants. In addition, once acclimated the biological filters retain the capacity to biodegrade micropollutants if there is an absence of exposure for less than 6 months. Nitrifying biological filters also will be able to biodegrade different sets of micropollutants than carbonaceous biological filters.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Biological filtration can reduce the exposure to micropollutants in drinking water. Once the capabilities and limitations are known, biological filtration can be used as a treatment technology for the removal of micropollutants in future regulations.

Keywords: *biological filtration, micropollutants, pharmaceuticals, endocrine disrupting compounds, personal care products, pesticides, treatment technique*

Ecosystem Services

Aquatic Systems Ecology

Terrestrial Systems Animal Ecology

Terrestrial Systems Soil and Plant Ecology

To halt the decline of an ecosystem,
it is necessary to think like an ecosystem.

– Douglas P. Wheeler
EPA Journal, September - October 1990

Ecosystem Services

Aquatic Systems Ecology

Terrestrial Systems Animal Ecology

Terrestrial Systems Soil and Plant Ecology

Aquatic Systems Ecology

Ecosystem Services: Aquatic Systems Ecology
University of Oklahoma (OK)
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EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Ecology & Ecosystems

Carla Lee Atkinson

E

Trophic Roles and Ecological Functions Provided by a Multi-Species Assemblage of Freshwater Mussels

Bio

Carla Atkinson received her B.S. in Biology from Missouri State University in 2006 and an M.S. in Ecology from the University of Georgia in 2008. She joined the University of Oklahoma Zoology Department in 2009 as a Ph.D. student in the Ecology and Evolutionary Biology program. For her dissertation research, she is studying the role of freshwater mussels, the most endangered faunal group in North America, in food webs and nutrient cycling. Her research combines knowledge on biogeochemical processes, biological communities and stream ecology to evaluate ecosystem services.

Synopsis

Freshwater mussels are the most endangered faunal group in North America and provide important ecosystem services (i.e., nutrient flux, nutrient storage and support of the food web). This project will use a combination of laboratory, mesocosm, and field experiments and observations to construct a model on how freshwater mussels utilize food resources and in turn alter the available nutrients in riverine ecosystems. With an understanding of the nutrient demands of a high biomass assemblage of freshwater mussels, scientists can start to understand their impact on the community under varying environmental fluctuations. This project tests the hypothesis that freshwater mussels alter the availability of nutrients in stream environments and create biogeochemical hotspots, but the impact of human-derived nutrients may supersede the impact. This will have immediate applicability to understanding the value of freshwater mussels in the role of supporting higher trophic levels and providing ecosystem services.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Complex feedback interactions within communities can maintain processes that ensure ecosystem services, including ecosystem processes that maintain clean water. Without these complex multi-step pathways, the flux of nutrients and materials can destabilize an ecosystem leading to unsustainable and undesired ecosystem response. Consequently, research on the nutrient processing of the speciose assemblages of freshwater mussels has significant implications for key regulating ecological processes in stream systems and will inform the conservation planning of these highly endangered groups. This research project will investigate the roles of diverse freshwater mussel assemblages in river food webs and nutrient cycling via these critical filter-feeding invertebrates.

APPROACH

Nutrient limitation is a key factor that structures biotic interactions within ecosystems. In stream environments, nutrients are taken up by organisms and cycled through the system downstream. Organisms like freshwater mussels may have a strong influence on nutrient cycling and alter ecosystem dynamics. Alteration of the nutrients in the environment influenced by large aggregations of mussels will be studied. This research will combine information on trophic partitioning of a diverse assemblage of freshwater mussels and relate the fixed internal nutrient requirements to the ratios of nutrients these organisms release back into the stream environment. This approach combines Physiology, Biogeochemistry and Ecosystem Ecology. During the summer of 2010, nutrient diffusing substrates (NDS) were used to determine the nutrients that limit primary production in areas of high mussel densities and no mussels. This was used to determine how mussels may influence nutrient dynamics. Controlled mesocosm experiments with NDS will further elucidate how mussels change nutrient dynamics. To investigate the diet of freshwater mussels, natural abundance stable isotopes (13C and 15N), a very powerful approach in determining patterns of energy flow and food web linkages in ecosystems, will be incorporated with stoichiometric analysis (%C, %N, %P and the molar ratios of these elements), available food resources and their excretion products to construct a mass balance model of nutrient flux. The combination of diet analysis and the stoichiometric analysis will lead to further understanding of the dietary requirements of multiple species of freshwater mussels. This research will lead to further understanding of the requirements of organisms and how this influences their environment.

EXPECTED RESULTS

With an estimate of the impact freshwater mussels have on nutrient flux, this research will allow quantification of an important ecosystem function mussels provide. Initial results show significant differences in the nutrients that limit primary production that occurred in areas with mussels (co-limitation) in comparison to areas without mussels (N-limitation). This suggests that mussels, through preferential uptake and excretion, are altering nutrient dynamics. The results also suggest mussels store large quantities of nutrients in their tissue that would otherwise be carried to downstream watersheds. To determine the contribution of freshwater mussels to nutrient storage and flux, a parameterized model will be developed to estimate the contribution of mussels to nutrient flux and storage using the estimates on nutrient composition and retention. The strength of this approach is that the model will combine information from high resolution laboratory experiments and more realistic field experiments. Additionally, mussels occur as speciose, dense aggregations known as mussel beds. This research also will investigate if trophic partitioning, through the use of stable isotope analysis, facilitates high species diversity in these high density mussel beds. In combination with this information, 15N-enriched mussels will be used as tracers to determine how mussel-derived nutrients travel through the stream food web. Through the combination of these approaches, information of the influence of organisms on aquatic ecosystem function will be gained.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research will examine the roles of freshwater mussels, the most endangered faunal group in North America, in relation to ecosystem services (i.e., nutrient flux, nutrient storage and support of the food web). A stronger understanding of the linkages between biodiversity and ecosystem services in freshwaters is needed. This will have immediate applicability to understanding the value of freshwater mussels in the role of supporting higher trophic levels and providing ecosystem services.

Keywords: *ecosystem services, nutrient storage, nutrient flux, freshwater mussels, water quality, stoichiometry, trophic partitioning, nutrient limitation*

Ecosystem Services: Aquatic Systems Ecology
North Carolina State University (NC)
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Bio-Environmental Engineering

Adrienne Rose Cizek

Ecosystem Services Provided by Regenerative Stormwater Conveyance (RSC) Systems

Bio

Adrienne Cizek received her undergraduate degree in Civil Engineering in 2006 from the University of Wisconsin-Madison. In 2008, she received a Master's degree from the School of Public Health at the University of North Carolina at Chapel Hill. Upon graduation, Adrienne worked as an engineer at Integrated Water Strategies in Apex, NC. Adrienne also has worked on water resource projects internationally in Rwanda, Peru and Haiti. In January 2011, Adrienne began research at North Carolina State University examining ecosystem services provided by nature-based stormwater control measures.

Synopsis

Regenerative stormwater conveyance (RSC) incorporates stream restoration principles into stormwater control design. This project will determine the effectiveness of RSC at achieving stormwater mitigation criteria, while providing additional ecosystem services. An estimation of the true value for RSC will be calculated, considering all the services provided by the system. Ultimately, this project will provide results to demonstrate how RSC can be used to achieve sustainable urban planning goals.

OBJECTIVE(S)/RESEARCH QUESTION(S)

An emerging interdisciplinary approach to stormwater management, referred to as regenerative stormwater conveyance (RSC), incorporates ephemeral stream restoration principles into structural stormwater control measures (SCM). Early studies on RSC systems observe that they adequately manage stormwater flows, while offering a suite of additional ecosystem services. This work intends to quantify the effectiveness of RSC at achieving typical stormwater mitigation criteria and additional ecosystem services by measuring the nutrient reduction, peak flow and volume reduction, carbon sequestration, biodiversity and habitat provision of different RSC systems in North Carolina (NC) and Maryland (MD). Ultimately, this research aims to estimate the true value of RSC systems, considering both the intended function (stormwater management) and the additional benefits (ecosystem services).

APPROACH

Research will be conducted on three newly constructed RSC systems in NC, two in the coastal plains and one in the Piedmont. These sites will be extensively monitored to better understand the ability of RSC and the hydrology involved in achieving volume control and water quality improvements. Sites will be monitored for 2 years. Additionally, the NC sites, along with a minimum of five existing sites in MD will be evaluated for carbon sequestration, biodiversity and habitat provision potential. The older MD sites will provide a perspective on ecosystem service establishment over time. Several existing stream reference sites also will be evaluated, chosen based on their proximity to the evaluated RSC systems. This work also will calculate the net present value of each system based on the services measured and the values provided by the literature to estimate an overall true value for RSC systems.

EXPECTED RESULTS

The anticipated scientific contributions of this research will be four-fold. First, this work will expand the limited current research on RSC systems by evaluating the ability of multiple RSC sites to manage stormwater runoff and by projecting performance over a variety of storm sizes. Second, this work will provide quantitative data in regards to the potential for RSC systems to exhibit additional ecosystem services, namely carbon sequestration, biodiversity and habitat preservation. Third, this work further contributes to the literature comparing ecosystem services present in engineered and restored systems to those present at natural reference sites. Fourth, this research will provide a method and results for estimating the true value of RSC systems. It is the intention of this work that such a method will be extended to the valuation of other SCMs, hence providing a more accurate means to determine the appropriate stormwater approach to a given situation. Additionally, as North Carolina State faculty members meet with State of North Carolina stormwater regulators semi-annually in regards to current stormwater regulation, it is the intention of this research to provide a basis for which to consider RSC systems as a viable and valuable option for urban stormwater management.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The ultimate goal of this research is to provide resources necessary for progressing sustainable urban planning. Urban planners around the world advocate for sustainable cities through efficient land use, pollution reduction, restoration of natural systems and sustainable ecology. This work will provide hard data, methods and models demonstrating how RSC systems and other SCMs necessary in every urban area can be used to achieve these sustainable urban planning goals.

Keywords: *stormwater control measure, regenerative stormwater conveyance, ecosystem services, engineered ecosystem, carbon sequestration*

Ecosystem Services: Aquatic Systems Ecology
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EPA Grant Number: FP917328
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Ecology & Ecosystems

Kauaoa Fraiola

E

The Effects of an Invasive Tropical Grass, *Pennisetum purpureum*, on Stream Nutrient Dynamics and Nitrogen Export

Bio

Kauaoa Fraiola first became interested in scientific research while growing up on his family farm in Waiahole Valley, where the intense legal battles and scientific research surrounding the restoration of flow to the valley's river took place. During his Bachelor's and Master's degrees, he studied the impact of invasive species and the ecology of streams in Hawaii, Micronesia and Puerto Rico. He is now in the Ph.D. program in the Department of Environmental Science, Policy and Management at the University of California, Berkeley, studying stream nutrient dynamics in Hawaii.

Synopsis

Nutrient pollution (e.g., nitrogen and phosphorous) has significant impacts on coastal communities and ecosystems, with streams and rivers being one of the major avenues along which these nutrients travel to the sea. One of the main ecosystem services that streams provide is the ability to remove nutrients from its water as it flows to the sea, an ability strongly influenced by the stream's biota. This project seeks to measure the affect that a widespread invasive grass, *Pennisetum purpureum*, has on uptake and export of nitrogen, and its contribution to stream food webs.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Stream and river ecosystems provide society with many ecosystem services, one of which is the uptake of nutrients from the water column, which helps to buffer coastal ecosystems from nutrient pollution. Given the knowledge that plants (vascular and non-vascular) can significantly impact the nutrient processes of streams, it is important to understand the impacts of invasive plant species on stream processes. This project will investigate the effects of a widespread invasive grass, *Pennistum purpureum* (Elephant Grass) on the downstream export of nitrogen and stream food webs.

APPROACH

A combination of a large-scale field manipulation and stable isotopic measurements in a Hawaiian stream will be used to investigate the effect that Elephant Grass has on nutrient dynamics and stream food webs. Measurements of nitrogen uptake/export and benthic primary productivity will be made using short-term nitrogen additions, routine water samples, upstream-downstream changes in dissolved oxygen and colonization tiles. These measurements will be taken before and after the manipulation, in both the control and manipulation stream sections. The role of Elephant Grass in stream food webs will be determined using C and N stable isotopes and a mixing model. Stable isotope measurements will be made using samples of stream biotic community and their potential food resources (detritus and algae) before the manipulation.

EXPECTED RESULTS

The results of this research are expected to increase knowledge of how Elephant Grass affects nitrogen uptake and export to downstream ecosystems, as well as its contribution as a basal food resource to stream food webs. These results will help resource managers better weigh the cost and benefits of Elephant Grass, which will in turn help them make more well-informed management decisions. The large-scale and manipulative nature of the study design also strengthens the inferences that can be made and the confidence through which results can be applied to management decisions. Lastly, in many tropical areas around the world, scientific understanding lags in comparison to those in temperate zones. This study also will help to increase understanding of nutrient dynamics in tropical streams and provide data on which future hypotheses might be built.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research may have the potential to further environmental protection in that it will help the understanding of how an invasive semi-aquatic plant species influences nutrient loading to coastal ecosystems. Findings from this research may spur more research into how invasive species impact this valuable ecosystem service, an understanding that is sorely lacking and lags behind the understanding of the effects of other anthropogenic impacts such as deforestation, wastewater and channelization. Understanding the broad impacts that invasive species, like Elephant Grass, have on the environment will help resource managers make well-informed decisions in the face of multiple stressors and multiple uses.

Keywords: Pennistum purpureum, *Elephant Grass, invasive species, nitrogen, nutrient dynamics, nutrient pollution, water, tropical streams*

Ecosystem Services: Aquatic Systems Ecology
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EPA Grant Number: FP917287
EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Ecology

Ben K. Greenfield

E

Modeling the Long-Term Fate and Bioaccumulation of Mercury, PCBs, DDTs and PBDEs in an Enclosed Estuary

Bio

Ben Greenfield researches the application of statistical and mechanistic models to determine the fate, bioaccumulation and human health risks of legacy and emerging pollutants. He is particularly interested in the interpretation of monitoring and modeling results for hazard and risk assessment, to forecast pollutant effects in aquatic ecosystems. For the past 10 years, he has worked as a contaminant scientist at the San Francisco Estuary Institute.

Synopsis

Ben Greenfield's primary aim in pursuing a Ph.D. is to use computer simulation models to forecast the impacts of management activities on pollution of estuaries and rivers. He also will examine how variation among locations and people affects individual exposure to water pollution. His research will evaluate and contrast historic pollutants, such as mercury, and recently introduced pollutants, such as currently used agricultural pesticides.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This study will use pollutant fate and exposure models to forecast the impacts of alternative management actions across a suite of pollutants in aquatic ecosystems. An additional objective is to determine the role that spatial heterogeneity and variability among individuals will play in influencing the health effects to the human population exposed to these pollutants.

APPROACH

The research plan is to use open-source multimedia contaminant fate, transport, exposure and toxicity models to contrast the time course of pollutant loss from aquatic ecosystems under alternative management scenarios. The toxicity evaluation will focus on forecasting changes in human health effects (i.e., disease burden) resulting from different management actions. This work will focus on potential pollutants of concern, evaluating risks at San Francisco Bay and the Mississippi River Basin. The study plans to compare legacy (e.g., mercury, PCBs) versus emerging (e.g., current use pesticides, PBDEs) pollutants to determine which is most likely to respond to management actions.

EXPECTED RESULTS

This work will build and verify new model extensions to evaluate the fate and exposure pathways of emerging pollutants, including PBDEs, current use pesticides and next generation biofuels compounds. The modeling activities will address three areas. First, by comparing among priority pollutants this study will aid in determining the likely benefit of alternative management approaches. It is predicted that compounds that have been used and released for over a century (e.g., Hg) or were banned decades ago (PCBs) will be far less responsive to management interventions than recently introduced compounds (e.g., PBDEs, current use pesticides). Second, the study will contrast the role of aquatic sediment versus other sources (e.g., terrestrial soils and ambient air) for pollutant exposure to humans. It is hypothesized that surface sediments will be the major source of legacy pollutants to human exposure, via the mechanism of food web trophic transfer, and consumption of local seafood and wildlife. In contrast, the exposure pathways for recently introduced compounds will be more complex, potentially requiring management interventions for multiple pathways. Finally, the study will evaluate the roles of heterogeneity for the extent and time course of human exposure to pollutants. Both spatial heterogeneity in pollutant fate processes and variability in the exposed human population will be examined. For example, it is hypothesized that in San Francisco Bay margin locations, accounting for the spatial and temporal heterogeneity in sediment processes will delay predicted contaminant loss from the system. Human population exposure will be assessed in a spatially explicit fashion, with model runs used to generate statistical distributions of exposure and movement of multiple simulated individuals. This will provide greater realism in depicting population-level variation in contaminant exposure.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

At regional and local scales, extensive technical and economic resources often are devoted to cleaning up legacy and emerging pollutants. With the continued introduction and use of new chemical compounds, many potential pollutants are emerging in natural waters. In many cases, exposure pathways and risks of greatest concern for future pollutants have not been yet thoroughly evaluated. In addition to informing local management, this study's technical activities will contribute to science and management applications for polluted waters nationwide. The model simulations of pollutant time trends should broadly interest scientists and managers concerned with forecasting legacy pollutant decline. Additionally, this work should provide useful case studies in the treatment of variability in determining pollutant risks.

Keywords: *multimedia fate models, water, bioaccumulation, emerging pollutants, environmental life cycle assessment, spatial heterogeneity, San Francisco Bay, Mississippi River Basin*

Ecosystem Services: Aquatic Systems Ecology
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EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Sciences/Policy and Risk Management

Bonnie Louise Keeler

E

Decision Support for Mitigating Water Pollution and Enhancing Other Ecosystem Services in Agricultural Landscapes

Bio

Bonnie Keeler is a Ph.D. student studying Environmental Science, Policy and Management in the Natural Resources Science and Management program at the University of Minnesota. Bonnie has a Master's degree in Ecology, where she studied the impacts of reactive nitrogen deposition on forests and grasslands. In her Ph.D. work, she is applying her background in biogeochemistry to decision-making on land use and land management using an ecosystem services framework. Her research interests include the economic valuation of water-related ecosystem services, spatial pattern and suitability of lands for service provision, and the economic and ecological consequences of biofuels expansion in the Upper Mississippi River Basin.

Synopsis

Bonnie Keeler's research uses an ecosystem services framework to address the effects of increased biofuel production with a particular focus on water quality and nitrogen-related services. She will develop models to assess the impacts of land change on ecosystem services and use economic valuation tools to assign a value to these changes. Results of her work will improve decision-making through a more comprehensive accounting of the environmental and economic trade-offs associated with alternative land use.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Water quality is a valued ecosystem service impacted by land use change and other human activities. Decision-makers increasingly are interested in the valuation of water quality as an ecosystem service. However, biophysical monitoring and modeling efforts are not well integrated with economic valuation tools and there is little consensus on how to best value changes in water quality. Similarly, reactive nitrogen impacts human health and affects many other ecosystem services but no consistent valuation framework exists for nitrogen-related services or the damage costs associated with increased reactive nitrogen in the environment. This research will expand and improve on these two critical frontiers of ecosystem services research with particular application to assessing the water quality and nitrogen impacts of land use change associated with biofuels expansion in the Upper Midwest, United States.

APPROACH

This research assesses how land use changes affect the biophysical production of ecosystem services, how these biophysical changes impact humans and how these impacts on people can be valued using economic techniques. The proposed research is structured around the following two aims: (1) Refine and expand an existing spatially explicit ecosystem services model, Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), to address water quality and nitrogen-related ecosystem services. Activities around this aim include biophysical model development and linking changes in biophysical outputs to economic valuation approaches; and (2) Apply the ecosystem services model and framework to the issue of biofuels expansion in the Upper Mississippi River Basin, United States. This work will include designing alternative land use scenarios to meet the Renewable Fuels Standard and assessing the ecological and economic consequences of different scenarios in terms of ecosystem services and returns to landowners.

EXPECTED RESULTS

End products of this research will include improved models for estimating the effects of land use change and land management on water quality and nitrogen impacts on human health, recreation and other ecosystem services. An important component of this work will be exploring alternative options for the economic valuation of water quality services and the damage costs associated with reactive nitrogen pollution. Model development work will contribute to the improvement of the InVEST model and be applied to the problem of biofuels expansion in the Upper Mississippi River Basin. This research also will focus on linking the ecosystem services model InVEST with other more complex process-based water quality models and vegetation models. Results of this analysis will determine how alternative scenarios of bioenergy production may impact ecosystem services and identify locations on the landscape where conservation activities can maximize potential ecosystem service flows.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Ecosystem services are increasingly incorporated into decision-making; therefore, improvements in the ability to assess changes in services and estimate the value of those changes are highly beneficial. This research addresses two issues of importance to human health and the environment: water quality and reactive nitrogen pollution. Improved modeling of these services, assessment of the value associated with changes in water quality and nitrogen cycling, and application to biofuels expansion, a key driver of land use change, will greatly improve the ability to make informed decisions about future land use change and conservation.

Keywords: *water quality, nitrogen, ecosystem services, land use change, biofuels, renewable fuels standard, InVEST, valuation, agriculture*

Ecosystem Services: Aquatic Systems Ecology
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EPA Grant Number: FP917280
EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Ecology & Ecosystems

Rebecca Anne Lloyd

E

Restoring Aquatic Ecosystem Services on the Clearwater National Forest Through Integrated Science and Management

Bio

After completing her Master's in Environmental Science and Water Resources at Indiana University, Rebecca Lloyd spent 10 years as a project manager and a hydrologist working for a very progressive integrated restoration partnership between the Nez Perce Tribe and Clearwater National Forest in Northern Idaho. After working on the restoration project, Rebecca began to develop questions regarding how to measure ecosystem recovery following large-scale restoration, specifically removal of extensive networks of failing, abandoned forest roads. To address these questions, Rebecca began a doctorate program in Ecohydrology at the University of Arizona. Rebecca's research will evaluate ecohydrologic recovery of watersheds following road reclamation and quantify how road restoration affects ecosystem services, such as water quantity and fisheries production.

Synopsis

Rebecca Lloyd's research will examine how reclaiming abandoned forest roads enhances recovery of ecological and hydrologic processes at the road and hillslope scale. She will research how road removal impacts freshwater ecosystem services, specifically the quantity of water and fisheries production, ultimately, quantitatively linking restoration to ecosystem services. Her research is integrated with the ongoing restoration work of the Clearwater National Forest and Nez Perce Tribe in North Central Idaho.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research will evaluate how restoring stacked forest road systems affect the recovery of ecological and hydrologic processes at multiple scales. This study will quantify recovery rates and evaluate road restoration within an ecosystem services framework.

APPROACH

This study will evaluate recovery rates of ecohydrologic properties with a combination of field sampling from transects established across a restoration age gradient and compare these to never roaded areas, and incorporate modeling to evaluate restoration impacts at a hillslope and watershed scale. Data collected will include above and below ground ecological structure, soil physical properties and nutrient pools/fluxes, and hydrologic characteristics. Models will incorporate field collected data, LiDAR data and numerical modeling of hillslope hydrology to synthesize and predict watershed response to restoration. Watershed responses will be evaluated in the context of how ecosystem service production is changed following road restoration.

EXPECTED RESULTS

This research will address critical gaps in scientific understanding regarding how to link ecosystem structure and function to ecosystem services by focusing on restoration through removal of extensive road networks. Results will include quantified ecohydrological recovery rates of removed roads compared to never-roaded reference areas. These results will be synthesized into a model to predict recovery at a larger scale and link recovery to changes in production of valued ecosystem services such as quantity of water and fisheries.

POTENTIAL TO FURTHER ENVIRONMENTAL/HUMAN HEALTH PROTECTION

Resource managers responsible for protecting valuable ecosystem services produced from public lands will benefit from research on watershed restoration. Given the accelerated emphasis on road removal, research on the function of restored hillslopes and response of different reclamation treatments becomes particularly pressing to support and improve these ongoing efforts. This will be the first research to frame road removal and watershed restoration within a larger context of protecting ecosystem services on which humans depend and how restoration may enhance aquatic ecosystem services such as clean and abundant water as well as fisheries production.

Keywords: *restoration, road decommissioning, ecosystem services, ecohydrology*

Ecosystem Services: Aquatic Systems Ecology
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EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Ecology

Maria Magdalena Meza-Lopez

E

Effects of Exotic Species and Nutrient Pollution on Native Aquatic Communities

Bio

Maria Meza-Lopez received her A.S. degree in General Science in 2006 from Santa Monica Community College. She received her B.S. in Biology in 2009 from the University of California, Los Angeles. She is currently a graduate student in the Department of Ecology and Evolutionary Biology at Rice University. Her research focuses on the biotic interactions between native and exotic aquatic plants and an exotic herbivore, including how the biotic interactions between native and exotic species and between exotic species may be altered by abiotic factors, such as nutrient enrichment.

Synopsis

Exotic herbivores often are found co-occurring at high densities with exotic plants in eutrophic aquatic ecosystems, but very little is known about the effects of eutrophication and the interactions between exotic species and the impact that they have on natural freshwater ecosystems. We will investigate if eutrophication enhances the interactions between native and exotic plants and exotic herbivores on native and exotic plants, and whether exotic snails increase the success of exotic plants.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Exotic herbivores often are found co-occurring at high densities with exotic plants in eutrophic aquatic ecosystems but very little is known about the effects of eutrophication and the interactions between invasive species and the impact that they have on natural freshwater ecosystems. This study will investigate if nutrient enrichment enhances the effects of competition between exotic and native aquatic plants, herbivory of the exotic snail on native plants and whether an exotic snail increases the success of exotic plants.

APPROACH

This study will quantify the individual and combined impact of exotic plants and exotic herbivores on a native community by establishing native communities in mesocosms and then introducing exotic species into the communities while varying environmental conditions (nutrient levels). The study will collect data on the native community before and after each exotic species introduction. At the end, the study will collect plant diversity and biomass and snail abundance and biomass.

EXPECTED RESULTS

Study predictions are that exotic snail herbivory on the native plant is going to have greater negative effects compared to competition between native and exotic plants. Herbivory by the exotic snail may facilitate the establishment of exotic plants. The predictions above will be magnified by nutrient enrichment contributing to the success of exotic aquatic species.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Investigating the biotic interactions between native and exotic species that determine native community composition and the effects that nutrient pollution may have on those biotic interactions is critical to determine if it is beneficial to manage and control exotic plants and/or exotic herbivores, and whether regulation of nutrient influx in aquatic ecosystems is important to protect native biodiversity. This study will provide information on how nutrient pollution may synergistically lead to declines in native species. This also will provide information on the relative importance of focusing on managing nutrient pollution and/or species invasions. This would be directly applicable to the conservation of freshwater ecosystems in Texas and also has economic and agricultural implications.

Keywords: *exotic species, biotic interactions, nutrient enrichment, freshwater, community*

Ecosystem Services: Aquatic Systems Ecology
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EPA Grant Number: FP917368
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Ecology & Ecosystems

Elizabeth Whidden Stoner

E

Effects of Nutrient Loading and Native Invaders on Structure and Function of Seagrass Ecosystems

Bio

Elizabeth Stoner received her B.A. in Environmental Studies with a concentration in Biology from Skidmore College. During her time at Skidmore, Elizabeth conducted research in the Turks and Caicos on point source pollution of mangrove habitats, sparking her interest on the effects of human disturbances in coastal ecosystems. Elizabeth also conducted work on the sublethal effects of copper sulfate on bluegill sunfish foraging behavior. Elizabeth is currently a Ph.D. candidate at Florida International University, where she studies nutrient enrichment of seagrass ecosystems.

Synopsis

Nutrient pollution is one of the most pervasive impacts to seagrass ecosystems. One threat to seagrass habitats are native invaders, or organisms that proliferate as a result of human disturbances. This project focuses on how the jellyfish, *Cassiopea* spp., may act as a native invader in nutrient-enriched seagrass beds by increasing and expanding its abundance, affecting seagrass habitats. This question will be addressed using surveys and *Cassiopea* manipulation experiments in seagrass beds.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The effects of anthropogenic nutrient loading on seagrass ecosystems have been well documented, with several impacts clearly identified, including a loss of seagrass biomass, changes in seagrass species present and an increase in opportunistic algae. However, little is known about the effects of increased native invaders, or endemic organisms that proliferate and expand their range as a result of human disturbance, on seagrass ecosystems. The objective of this research is to address whether increased densities of the potential native invader, *Cassiopea* spp., previously shown to be more abundant in nutrient-enriched coastal habitats, leads to a shift in sub-tropical seagrass benthic community structure and ecosystem function.

APPROACH

This research question will be broken into two major components. The first is to use a series of descriptive surveys to address whether a natural gradient in *Cassiopea* densities correspond to altered benthic community structure and seagrass health. Several parameters will be evaluated in this component, including epiphyte community composition and biomass, seagrass blade height, benthic invertebrate community structure and zooxanthellar densities within *Cassiopea* jellyfish tissue. The second component of this research will be to experimentally manipulate *Cassiopea* densities in seagrass ecosystems using a press design to remove jellyfish, and add jellyfish to two, extensive seagrass meadows. Benthic community structure and ecosystem function of the seagrass beds will be examined *a priori*, as well as at the conclusion of the study.

EXPECTED RESULTS

As little is known about the role of anthropogenic nutrient loading and benthic jellyfish as native invaders in seagrass ecosystems, this research will provide a better understanding of how anthropogenic nutrients may lead to widespread shifts in seagrass community structure and functioning. In both the surveys and manipulative experiments, it is expected that there will be reduced species richness and abundance, decreased seagrass health and altered seagrass ecosystem functioning as a result of increased jellyfish densities.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Cassiopea jellyfish and anthropogenic nutrient loading are prevalent in coastal habitats in several parts of the world. Therefore, this research has broad-reaching implications for many coastal ecosystems that are under the threat of nutrient pollution, as the subsequent proliferation of *Cassiopea* among other jellyfish, may result in a decline in coastal ecosystem integrity. Humans rely substantially on coastal ecosystems for many commercially viable species, as well as revenue from tourism, which can be affected by native invaders. Ultimately, this research may elucidate ways to mitigate effects of nutrient pollution and native invaders on coastal ecosystems.

Keywords: *native invaders, nutrient pollution, benthic,* Cassiopea *spp., seagrass, ecosystems, communities, function, estuaries, sub-tropics, jellyfish*

Ecosystem Services: Aquatic Systems Ecology
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Systems Ecology

Roy E. Weitzell

E

Landscape Connectivity of Headwater Stream Systems as a Measure of the Cumulative Impacts of Stream Burial During Urbanization

Bio

Roy Weitzell received his undergraduate degree in Marine Biology from the University of North Carolina at Wilmington in 1994, and his M.S. in Zoology from Southern Illinois University at Carbondale in 1998, where he specialized in the ecology and systematics of freshwater fishes. After 10 years of working in freshwater ecology and conservation positions, he entered the Marine Estuarine and Environmental Science Ph.D. program at the University of Maryland. Currently in his second year, Roy studies the effects of stream burial on network connectivity and biodiversity in headwater stream ecosystems.

Synopsis

Headwater streams are unique and critical components of aquatic networks, yet have been disproportionately buried by urbanization as compared to larger systems. Knowledge of the cumulative impacts of reduced structure and function within buried stream networks is crucial for informing management of stream ecosystems. This project will combine innovative remote sensing and connectivity modeling methods to form a novel statistical approach to quantifying the impacts of urbanization on ecosystem structure and function.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Landscape changes that reduce habitat area and restrict the dispersal abilities of organisms between habitat patches have a strong influence on biodiversity and ecosystem functioning. With urbanization continuing at a rapid pace across the Potomac River Basin (PRB), many streams are at risk of being buried, presenting serious implications for water quality and regional biodiversity. Knowledge of the cumulative impacts of reduced structure and function within buried stream networks is crucial for informing management of stream ecosystems in light of continued growth in urban areas and the uncertain response of freshwater ecosystems to the stresses of global climate change.

APPROACH

New developments in Geographic Information Science (GIS) and remote sensing-based methodologies allow for accurate measure of the former extent of headwater streams and the severity of burial across large areas. These data can be coupled with existing techniques for modeling landscape connectivity within and between aquatic networks impacted by urbanization, and to quantify how burial may alter the potential flow of organisms and materials. In turn, models of network connectivity can be considered in light of long-term biological and environmental datasets to quantify the ecosystem effects of stream burial at multiple spatial scales.

EXPECTED RESULTS

This research will quantify stream burial totals for the Potomac River Basin (PRB) at four previous time steps, and assess burial patterns relative to other measures of urban effects on stream ecosystems (e.g., total imperviousness). This work will establish an understanding of the range in stream burial relative to these more traditional measures of the impact of urbanization (i.e., where does stream burial occur less frequently at the same level of TI). Secondly, landscape connectivity measures will provide valuable information on the cumulative effects of stream burial on between-habitat dispersal in headwater stream ecosystems, both within the channel networks themselves, as well as across the upland landscape. Finally, maps of headwater stream burial and connectivity will be used to determine how urbanization has altered patterns of biodiversity, including the distribution of headwater macroinvertebrates, organisms that play critical roles in ecosystem dynamics affecting local and downstream waters such as the Chesapeake Bay.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This project will provide three integrated spatial products to be used in regional conservation and management of headwater stream systems and the ecosystem services they provide. Taken together, analyses of fragmentation of headwater systems will provide critical information on cumulative impacts of buried streams necessary for monitoring and regulating development pressures on aquatic resources.

Keywords: *headwater streams, stream burial, cumulative impact, urbanization, connectivity, beta-diversity*

Terrestrial Systems Animal Ecology

Ecosystem Services: Terrestrial Systems Animal Ecology
Florida State University (FL)
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Toxicology

Joshua Bradley Grinath

E

The Effects of Nitrogen Deposition on Cascading Interspecific Interactions in a Mutualistic/Antagonistic Food Web

Bio

Josh Grinath received his undergraduate degree in Natural Resource Management from Cornell University in 2004. He then began work as a research assistant and manager for the Billick/Reithel laboratory at the Rocky Mountain Biological Laboratory (RMBL) in Colorado. After 3 years of travel and work, Josh began the Ph.D. program in Ecology and Evolutionary Biology at Florida State University. His research focuses on the impacts of atmospheric nitrogen pollution on a widespread meadow ecosystem at RMBL.

Synopsis

This research will examine how atmospheric nitrogen pollution causes changes in the strengths of interactions among species in a widespread ecosystem in the western United States. Using an experiment that mimics high levels of nitrogen deposition in a nitrogen-poor mountain meadow, the research will test whether increased nitrogen results in stronger trophic cascades, whereby ants will have stronger effects on herbivorous bugs and the plants they live on, which is important for the functioning of the ecosystem.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Humans have dramatically altered earth's nitrogen cycle by increasing the availability and mobility of biologically useful forms of nitrogen; specifically, atmospheric nitrogen deposition has increased due to oxides of nitrogen emitted from fossil fuel combustion and ammonia and ammonium emitted from agricultural operations. In nitrogen-limited ecosystems, the food quality hypothesis predicts that enhanced food quality due to nitrogen pollution will cause greater magnitudes of top-down trophic cascades, whereby upper trophic levels (predators/omnivores) have greater effects on lower trophic levels (herbivores and plants). This study asks: (1) does nitrogen deposition cause stronger cascading interspecific interactions? and (2) do the interactions become stronger as N:C stoichiometric mismatches decrease between consumers and resources?

APPROACH

This study is being conducted in a nitrogen-poor mountain meadow in Colorado, and focuses on cascading effects in a food web composed of antagonistic (negative) interactions between two honeydew-producing herbivores and their shared host plant, and mutualistic (positive) interactions between an ant and these honeydew-producers. This study will conduct a nested factorial field experiment manipulating nitrogen availability to mimic pollution levels elsewhere in the western United States and the presence or biomass of each of the four focal species within 36 single ant nest enclosures. The magnitude of the cascading interactions between ants and plants will be measured at both the *per capita* and total population levels, and interaction strengths will be compared between fertilized and unfertilized food webs using structural equation modeling (SEM) and ANOVA analyses. Also, stoichiometric N:C in the four focal species and in honeydew resources will be analyzed to test how N:C mismatches relate to cascading interaction strengths and to track the flux of nitrogen through the food web.

EXPECTED RESULTS

This experiment will test how interspecific interaction strengths are affected by increased nitrogen deposition, where cascading effects are expected to become stronger due to higher food quality and decreased stoichiometric mismatches between consumers and resources in nitrogen-polluted food webs. This study also tackles the challenge of integrating mutualistic and antagonistic interactions into a single food web and uses multiple ecological currencies and metrics to compare interaction strengths to other studies and to examine how they affect the interpretation of interaction strength. It is hoped to continue nitrogen treatments in the experimental plots to ask how the strength of these interactions will change due to increased nitrogen deposition in the long term.

POTENTIAL TO FURTHER ENVIRONMENTAL/HUMAN HEALTH PROTECTION

This study has the potential to contribute to regulatory decisions for pollutants causing nitrogen deposition. Representing fluxes of energy and nutrients among species, the interaction strengths measured in this study have important consequences for species productivity and dominance. By using an experimental nitrogen treatment mimicking high levels of nitrogen deposition occurring in the western United States, this study will provide evidence for how atmospheric nitrogen pollution is affecting ecosystem functioning in a widespread type of system.

Keywords: *nitrogen pollution, atmospheric nitrogen deposition, trophic cascade, plant quality hypothesis, ecological stoichiometry, honeydew mutualism, interspecific interaction strength, structural equation modeling, food web*

Ecosystem Services: Terrestrial Systems Animal Ecology
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EPA Grant Number: FP917306
EPA Project Officer: Brandon Jones
Project Period: 9/1/2010 – 8/31/2012
Project Amount: $74,000.00
Environmental Discipline: Agricultural Engineering

Rhea Hanselmann

E

Toxic Effects of Herbicides and Pesticides on Immunocompetence and Zoonotic Disease Dynamics in Wild Deer Mice (*Peromyscus maniculatus*)

Bio

Rhea Hanselmann received her B.Sc. degree in Biotechnology from Worcester Polytechnic Institute in 2001. She was accepted to Tufts University School of Veterinary Medicine the same year and received her doctoral degree and a certificate in International Wildlife Conservation Medicine in 2005. She then worked in clinical practice, completing postdoctoral fellowships in both medicine and anesthesia. In 2009, she completed a Master's in the Preventive Veterinary Medicine program at the University of California, Davis, focusing on wildlife and ecosystem health. She was a Smithsonian Institution postdoctoral fellow at the Mpala Research Center in Kenya in 2009. Since 2010, she has been enrolled in a Ph.D. program at Oregon State University studying the impacts of anthropogenic environmental changes on disease in wildlife.

Synopsis

Toxic compounds and management interventions used in intensive agricultural systems can compromise the health and immunity of wildlife. This is particularly important when reservoir species for human and animal diseases are affected. Using a major carrier of zoonotic pathogens, the deer mouse (*Peromyscus maniculatus*), Rhea will explore the effects of intensive agriculture on the functioning of the immune system, and the impacts of these environmental interventions on zoonotic disease prevalence.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This proposed research evaluates the effects of toxic compounds and management interventions commonly used in intensive agricultural systems, on health, immunity and disease risk in a zoonotic reservoir species, the deer mouse (*Peromyscus maniculatus*). Two central relationships will be explored: (1) the effects of agricultural management practices on the normal functioning of the host immune system, and (2) the impacts of these environmental interventions on prevalence of important zoonotic diseases.

APPROACH

In a first study phase, wild deer mice will be live-trapped in experimental field plots varying in management intensity, located on area-typical silviculture and grass-seed farmlands. During a second phase, the effects of agricultural herbicides and pesticides on wild deer mice health, immunity and disease dynamics will be evaluated in large-scale experimental rodent enclosures. Blood and fecal samples, as well as numerous morphometric measurements will be collected from all animals. To assess the impact of management strategies and chemicals on health and immunity, assays will be performed to measure physiologic function (i.e., stress, condition, immune function). Prevalence of three endemic zoonotic diseases (*Leptospira* spp., *Toxoplasma gondii*, and Sin Nombre virus) will be determined using serologic assays. Gastrointestinal parasite prevalence and infection intensity will be determined using standard fecal analysis techniques. Finally, various analytical methods will be used to evaluate treatment effects.

EXPECTED RESULTS

This proposed study will elucidate the potential impact of harsh management strategies and chemical compounds commonly used in intensive agricultural systems (i.e., herbicides and pesticides) on an important ecosystem service: disease abatement. Conventional agricultural methods adversely can affect wildlife populations both directly via toxicity and/or habitat loss, and indirectly via stress and/or loss of condition resulting from changes in community structure. Here, it is expected to see impaired health and immunocompetence in animals exposed to harsh management practices, when compared to those in minimally managed areas. As a result, it also is expected that disease prevalence will be higher in animals inhabiting intensively managed areas, and therefore, that intensive agricultural practices intensify infectious disease risk in the environment.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Even in species that appear relatively resilient to environmental change, anthropogenic stressors can have negative impacts on health and immunocompetence. This can make host animals more susceptible to endemic and emerging diseases, which in turn can lead to increased disease prevalence and amplify pathogen transmission in affected animal populations. Ultimately, this exacerbates the risk of disease posed to animals and humans entering impacted ecosystems. Understanding the mechanism and degree to which this occurs is fundamental to the development of plans for environmental and human health risk assessment and protection.

Keywords: *ecosystem health, ecosystem service, wildlife health, zoonotic disease, agricultural impact, environmental stressor, anthropogenic environmental change, herbicides, pesticides*

Terrestrial Systems Soil and Plant Ecology

Ecosystem Services: Terrestrial Systems Soil and Plant Ecology
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Plants and Soils

Brittany Marie Bernik

E

The Effect of Genotypic Variation in *Spartina alterniflora* on the Ecosystem Services Provided by Coastal Marshes

Bio

Brittany Bernik received a Bachelor's degree in Environmental Biology at Tulane University, and entered the Ph.D. program in Ecology & Evolutionary Biology in 2008. Investigating marsh genetic response to environmental change, she earned a Master's in 2010. Her current work uses a "genes to ecosystems" approach to understand marsh processes and resilience. Focusing on the interface of human and natural systems, she is looking at how the genetics of restored marshes influences ecosystem services.

Synopsis

Marsh restoration relies on a few genotypes of Smooth Cordgrass, cultivated for easier propagation. However, this plant species is a known ecosystem engineer that influences its environment in diverse ways. A population's genotypic identity can strongly influence marsh properties. Using greenhouse and field experiments, this project investigates how ecosystem services, such as water treatment and flood protection, will be affected by using cultivated versus native genotypes for marsh restoration projects.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This project seeks to examine variation in ecosystem services arising due to the genetic identity of foundational marsh plants used for restoration—particularly between cultivated and wildtype clones. To this end, the study will meet the following objectives: (1) quantify phenotypic variation across genotypes; (2) quantify differences in marsh accretion across genotypes; and (3) quantify differences in agricultural pollutant amelioration across genotypes.

APPROACH

Greenhouse experiments will be used to assess variation in plant functional traits between genotypes. Traits expected to influence the provisioning of ecosystem services will be measured, including above and belowground biomass, root and rhizome distribution, canopy height and stem density. Transplantation field experiments will compare sediment and vegetative accretion across cultivated and wildtype clones using radiometric dating and by quantifying soil organics. Separate greenhouse trials will administer nutrient loading treatments, and water nitrate levels will be monitored across genotypes to evaluate differences in excess nutrient removal.

EXPECTED RESULTS

Genotypes will differ significantly from one another, with cultivars showing the strongest differences in plant functional traits, both from each other and from wildtype plants. Genotypes with denser root mats and a higher proportion of belowground biomass will survive and accrete more organics, while genotypes exposing more shoot surface area will have higher accretion of mineral sediments. Nutrient uptake also will differ between genotypes, with some clones showing greater potential for water treatment.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Marsh restoration increasingly relies on cultivars developed for ease of propagation. This project will provide information on how using these genotypes affects marsh accretion and nutrient uptake—services that provide flood protection and storm buffering, as well as water treatment that ameliorates the hypoxic "dead zone" in the Gulf of Mexico.

Keywords: *community genetics, ecosystem engineering, ecosystem services, marsh restoration,* Spartina alterniflora

Ecosystem Services: Terrestrial Systems Soil and Plant Ecology
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Sara Katrin Enders

E

Natural Abundance Stable Isotope Methods Reveal History and Fate of Nitrogen Cycles at the Watershed Scale

Bio

Sara Enders received a B.S. in Geology and Geophysics from Yale University in 2006. She worked in the White Mountains of New Hampshire for the Appalachian Mountain Club and as a Research Analyst for The Cadmus Group, Inc., before getting interested in improving the integrated management of land and water resources drew her back to school. She completed an M.E.Sc. from the Yale School of Forestry and Environmental Studies, where her thesis explored participatory, science-based, transboundary watershed management in Honduras and Nicaragua. Now in her second year of a Ph.D. program in Soils and Biogeochemistry at the University of California, Davis, in the Houlton laboratory, Sara's research uses isotope models and field measurements to explore interactions between nitrogen cycling and climate change.

Synopsis

Humans have doubled the amount of nitrogen (N) available to organisms. Yet the fate of this N in the environment remains unclear. N can act as an essential nutrient, a toxin or a greenhouse gas, depending on where it ends up and in what chemical form. This research focuses on understanding terrestrial ecosystem N budgets—the balance between how much N enters and leaves a landscape, and whether lost N will leak into streams or to the atmosphere—and how climate change will affect these budgets.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research targets the following three questions: (1) How will climate warming of the California Sierra Nevada affect the amount of nitrogen available to fuel forest C storage in the future? (2) Can nitrogen isotope-based mass-balance models be used as a management tool at the watershed-scale—particularly for estimating gaseous N emissions from the soil? (3) Can nitrogen isotopes of soil compounds be used to make inferences about pre-anthropocene nitrogen cycling on modern landscapes?

APPROACH

This work will improve the understanding of climate controls on the nitrogen cycle in modern and past terrestrial landscapes via new nitrogen isotope techniques. This study will first develop an isotope-based model to partition gaseous and hydrologic nitrogen losses at the watershed scale across a rain-snow transition in California's Sierra Nevada. This work will inform prediction of how warming of the Sierra will affect nitrogen and carbon cycles. Further, this work will develop a novel method to investigate pre-anthropocene terrestrial nitrogen cycling on this and other landscapes through the use of novel paleo-isotope techniques.

EXPECTED RESULTS

Expected results of this work include: (1) development of a watershed-scale model of climate controls on the form of nitrogen losses from a watershed; (2) prediction of gaseous and hydrologic fluxes of nitrogen responses to climate change in the Sierra Nevada; and (3) development of a soil compound-based proxy for terrestrial nitrogen cycling on past landscapes—prior to anthropogenic impact and under past climate conditions. Results will improve understanding of natural and anthropogenic terrestrial ecosystem nitrogen cycling and the ability to manage nitrogenous pollution. Further, this research will make more powerful the tool of natural abundance nitrogen isotopes by increasing the interpretability of nitrogen isotope variations now and in the past.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This work will inform efforts to regulate pollution, to value ecosystem services and to predict the ability of the biosphere to absorb increases in atmospheric CO_2 as the climate warms.

Keywords: *nitrogen, isotopes, soil, denitrification, nitrous oxide, nitrate, California, Sierra Nevada, mountain, forest, snow, climate, forests, biogeochemistry, ecosystem services, terrestrial, paleoclimate, precipitation*

Ecosystem Services: Terrestrial Systems Soil and Plant Ecology
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Civil/Environmental Engineering

Nicolas Adam Jelinski

E

Dissolved Organic Nitrogen Transport and Transformations From Tile-Drained Agricultural Systems to Surface Waters

Bio

Nicolas Jelinski received his undergraduate degree in Botany and Biology from the University of Wisconsin-Madison in 2004. While studying towards his B.S., Nicolas worked in land management and ecosystem restoration throughout southern WI and IA with private companies, NGOs and state agencies. He completed an M.S. in Land Resources with an emphasis in Soil Science from the University of Wisconsin-Madison in 2007, and began his Ph.D. studies in the University of Minnesota-Twin Cities Department of Soil, Water and Climate in 2010. He broadly is interested in the connections between biological and weathering processes in soils under different types of land use, and how those factors affect downstream water quality.

Synopsis

Dissolved organic nitrogen (DON) is an important part of the total dissolved nitrogen (TDN) loads of waterways throughout the United States; however, most of the impacts and monitoring of nitrogen have centered on dissolved inorganic nitrogen (DIN) in the form of nitrate, which is not reflective of the entire problem. To better understand and predict the effect that terrestrial systems can have on DON levels in waterways, there is a critical need to understand the transport and transformations of organic nitrogen, DON and organic matter in both solid and adsorbed forms in soils. The two main factors that influence the transport and transformation of organic nitrogen are the biological degradation and mineralization of nitrogen in organic matter and the association of organic matter with mineral particle surfaces and iron and aluminum oxyhydroxides. This project will study this in the agriculturally important tile-drained soils of southern Minnesota.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Dissolved organic nitrogen (DON) is an important part of the total dissolved nitrogen (TDN) loads of waterways throughout the United States; however, most of the impacts and monitoring of nitrogen have centered around dissolved inorganic nitrogen (DIN) in the form of nitrate. To better understand and predict the effect that terrestrial systems can have on DON levels in waterways, there is a critical need to understand the transport and transformations of organic nitrogen, DON and organic matter in both solid and aqueous forms in soils. This project will investigate the fundamental processes and drivers of DON delivery to waterways through the extensive tile-drained agricultural systems of the Upper Midwest. The primary objectives are to determine how different fractions of the bulk DON pool change as they move from residue layer leachate to surface flow in agricultural landscapes, and the spatial scale at which in-stream processes become more important than upland export of DON to surface waters.

APPROACH

This project will monitor chemical changes in the DON pool in agricultural soils and associated waterways both spatially and temporally over a multi-year period. Additionally, investigation into the long-term rates of production of new mineral surfaces and the extent of mineral occlusion by organic matter—which affects physical adsorption and DON export in tile-drained landscapes—will allow a better determination of transport rates for DON. Lastly, to determine the spatial scale at which in-stream processes become more important than the upland export of DON, seasonal changes in DON and TDN in successively larger downstream waterways will be monitored.

EXPECTED RESULTS

This research will contribute to a holistic understanding of water quality in intensively managed landscapes as it will focus on the organic portion of the TDN load, which is often overlooked but is greatly affected by the plant-soil system. Furthermore, it will provide a foundation for fully integrating the connections between physical and biological processes in upland and aquatic environments and how those processes can either enhance or detract from downstream surface water quality.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This project is expected to result in a unique perspective and a new, more fundamental understanding of DON export from terrestrial to aquatic systems—particularly those where the hydrology and soils have been radically altered by human activity—which will lead to better modeling and interpretation of data increasingly collected by many agencies that monitor DON and TDN in waterways. This is critical in many rural areas that are dependent on surface waters for primary water supply or drought contingency planning. Many of these areas are dependent on rural water networks, which provide waters that have a large array of end-uses, making holistic perspectives on water source quality a critical priority.

Keywords: *dissolved organic nitrogen, organic matter, mineral weathering, soil, water quality*

Emerging Environmental Approaches and Challenges

Information Science

Innovative Investigations for Oil Spill Impacts

Social Sciences

How wonderful it is that nobody need wait a single moment before starting to improve the world.

– Anne Frank

Emerging Environmental Approaches and Challenges

Information Science

Innovative Investigations for Oil Spill Impacts

Social Sciences

Information Science

Emerging Environmental Approaches & Challenges: Information Science
University of California, Berkeley (CA)
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EPA Project Officer: Ted Just
Project Period: 9/1/2010 – 8/31/2013
Project Amount: $111,000.00
Environmental Discipline: Environmental Decision Making

Erich Huffaker

E

Assessing the Emissions Impacts of Demand Response Programs Due to Diesel Backup Generation in California

Bio

Erich Huffaker was raised in Riverside, California, and graduated with a degree in Global Economics from University of California, Santa Cruz, in 2005. He spent the next 3 years promoting technology as a means of economic development with various nonprofit organizations in Mali as an IT consultant, web designer and teacher. Upon returning to the United States, he began a dual Master's degree program at the Goldman School of Public Policy and the Energy and Resources Group at the University of California, Berkeley. His research there has focused generally on the promise, potential and obstacles that demand-side strategies and technologies hold for moving to a lower carbon energy economy. He worked as a graduate student researcher at the Lawrence Berkeley National Laboratory's PIER Demand Response Research Center and spent the summer of 2010 exploring the extent to which California demand response program participants rely on backup diesel generation at the Energy Division of the California Public Utilities Commission. He is an avid biker and speaks Spanish, French and Bambara (Malian dialect).

Synopsis

Demand response (DR) has played a growing role in the plans to revitalize the grid. However, increasing shares of participants in DR programs have been relying heavily on heavy polluting diesel backup generators (BUGs) to meet the electricity reductions mandated by their programs. This project examines the trade-off between the energy goal of peak demand reduction that characterizes DR and environmental concerns over the threat that diesel emissions pose for human health and air quality.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Many have attested to the value of Demand Response (DR) in maintaining grid stability and reducing peak demand. However, not much research has looked at its environmental impacts. Specifically, what are the emissions impacts in California of the backup diesel generators (BUGs) that many DR participants rely on to meet their curtailment obligations?

APPROACH

The basic approach will be to utilize recently available data on when BUGs run within the State of California to assess cumulative emissions impacts. First, the study aims to obtain and format the run-time logs, which detail the specific usage patterns of BUGs in California. Then, the study will identify which of these BUG owners also are participants in DR programs. The hours of BUG usage will be cross-referenced against the schedule of events for various DR programs, providing a target number of hours that BUGs are used for DR. Then, the study can assess the emissions rates of PM, SO_x, NO_x and any other relevant criteria pollutants for each of these generators. The next step will be to create a simple spreadsheet tool that policy makers may use to input raw data on BUG usage. The output of the tool will be emissions rates that air quality modelers can utilize to determine specific local effects.

EXPECTED RESULTS

There is a dearth of research examining the specific impacts of BUGs in demand response. However, one previous study in 2005 attempted to quantify the impacts using modeling tools, finding that the impacts of such usage were significant and negative overall. It is likely that this study underestimated the cumulative effects that the current study's results will uncover. As a result, the study expects to find that the usage of these generators poses a significant threat to the environment and air quality.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Long-term exposure to PM has a well-acknowledged history of correlation with lung cancer and cardiovascular disease. PM emissions drive up the overall risk factor of pollution in an area. Concentrations of BUGs are highest in urban areas, so their emissions have a proportionally higher impact per capita. In addition, BUG pollution from DR occurs on event days that are typically the hottest, smoggiest days of the year. In sum, this study will aim to give insight in PM and other emissions that occur in the worst possible places, at the worst possible times.

Keywords: *BUGs Demand Response, emissions impacts demand response, diesel generators demand response, demand response air quality, diesel generators, backup generators, particulate matter (PM)*

Emerging Environmental Approaches & Challenges: Information Science
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Terrestrial Ecology and Ecosystems

Christine Marie Laney

E

Cyberinfrastructure to Improve the Usability of Environmental Observations

Bio

Christine Laney received her B.S. in Biology from the University of Puget Sound in 1996 and her M.S. in Biology from New Mexico State University in 2005. From 2005 to 2010, she coordinated the EcoTrends project (http://www.ecotrends.info), making long-term ecological data from 50 U.S. research sites easily accessible for comparison, visualization and download from a single website. As a student in the Environmental Science and Engineering Ph.D. program at the University of Texas at El Paso, her research focuses on informatics and cyberinfrastructure to support environmental sensor networks.

Synopsis

More data are needed to understand the complex relationships between climate change and ecosystems on which human well-being depend. Researchers are deploying networks of small automated sensors to continuously gather CO_2, water and energy flux data. However, managing information-rich data streams is challenging, especially for small laboratories. This project will yield a flexible cyberinfrastructure that can be used to facilitate data analysis and knowledge sharing.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The overarching goal of this research is to create a useful, modular local cyberinfrastructure (CI) that will help small laboratories to: (1) curate and share their data efficiently while adhering to nationally recognized standards, (2) compare their data with data collected by larger research networks, and (3) scale their data from local to regional and global scales. The overarching research questions addressed by this study are: (1) What are the best practices for researchers at small laboratories who wish to organize their work such that they meet their own research goals while making their data discoverable and usable for data synthesis efforts? (2) What kinds of CI and best practices will connect researchers at small laboratories to broader scale data curation and analysis efforts? (3) What kinds of CI will best combine distributed data at multiple spatial scales?

APPROACH

This study will first do a literature search and interviews of small laboratories that collect environmental, and specifically carbon cycling data to determine how they currently organize their work and information. Following an IRB-approved protocol, interviews and focus group sessions will be conducted at national meetings such as the Ecological Society of America and the American Geophysical Union. Next, the study will work with members of the Cyber-ShARE team to design, build, implement, validate and verify the new CI framework. The first phase of this project will be to set up a prototype to curate and analyze data collected by the Systems Ecology Laboratory (SEL) at a research site at the Jornada Experimental Range, within the northern range of the Chihuahuan Desert. The second phase will bring external data in for integration with local data and will set up protocols for distributing data and documentation to other data centers or projects. The third and final phase of this project is to promote use of the CI framework and modules outside of the Jornada research group, and obtain feedback on its usability and usefulness.

EXPECTED RESULTS

Research in the new fields of ecoinformatics and environmental applications is essential for answering urgent, applied earth system questions. The expected outcome of the research is a validated, flexible CI framework that can be used, modified and shared by small laboratories to facilitate knowledge and data sharing, and that can evolve over time with users' evolving needs. Such a CI will allow for bottom-up modifications while keeping national frameworks and goals of data management in focus. The CI framework and modules developed for this project, posted online as a free and dynamic resource, may encourage laboratories to set up their own robust CIs and improve data sharing. Researchers in both the environmental and computer sciences will be encouraged to modify existing or create new modules, keeping national initiatives in mind, to address other lines of ecosystem or earth system research. This could include curating and discovering air and water quality, human health and agricultural data, providing a platform for synthetic studies of human-environment interactions. Eventually, such data-supported activities could inform efforts by EPA regarding the Clean Air and Clean Water Acts. This set of bottom-up activities meeting top-down environmental information management efforts may help transform ecological information management and sharing.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The testing of this CI during each phase of development will not only tell us about the efficacy of the new CI, but also about regional environmental processes, which ultimately have implications to the burgeoning population in the desert southwest. Being able to describe carbon cycling at a regional level by quickly analyzing datasets collected locally and comparing them to datasets from different sites within the region can promote rapid assessment of ecosystem health and productivity. Being able to share data regionally will promote collaborations, which will be able to more quickly assess patterns in the data.

Keywords: *ecology, informatics, cyberinfrastructure, environmental science*

Emerging Environmental Approaches & Challenges: Information Science
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EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Jonathan Edward Mellor

E

Agent-Based Modeling as a Tool for the Prevention of Early Childhood Diarrhea

Bio

After finishing his M.S. degree in Physics at the University of Virginia (UVA), Jonathan Mellor enrolled in the Master's International Program at Michigan Technological University that combines coursework with practical work in the Peace Corps, for which he worked as an environmental engineer in Uganda. His M.S. research investigated rural water collection efforts and water usage, as well as a comparative study about the effectiveness of different water and sanitation interventions. He is now at UVA working on his Ph.D. studying the complex causes of diarrheal diseases in South Africa.

Synopsis

This research will develop an agent-based computer model to simulate the complex relationships of water and sanitation practices and childhood diarrhea in South Africa. This transdiciplinary project will use field data from a community about water and sanitation practices, and pathogen sources. Varying input parameters, like water source pathogen levels, will elucidate interventions that may be most effective at reducing diarrhea. The model can be a tool for researchers and policy makers worldwide.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Early childhood diarrhea (ECD) causes nearly 1.5 million child deaths worldwide each year. But the causes of and the prevention strategies for ECD are numerous and complex. Therefore, the purpose of this research is to create an agent-based model (ABM) to simulate the transmission of harmful pathogens that are the primary cause of ECD in much of the developing world. That model can then be used to predict which interventions will be most effective at stopping ECD and to explore the complex relationships related to this transmission.

APPROACH

The ABM, which is inherently transdisciplinary, will be validated and calibrated using field data collected from two adjacent communities in Limpopo Province, South Africa. Those communities are being studied as part of a long-standing partnership between the University of Virginia and the University of Venda in Thohoyandou, South Africa. Data about pathogen sources as well as sanitation and behavioral practices will be gathered using community surveys, microbiological testing and pathogen growth, decay and transmission measurements. These data will inform the development of the geo-spatial ABM in which the "agents" will be the community members who can make decisions about their adherence to sound water and sanitation practices. Varying input parameters such as water source pathogen levels will elucidate which interventions may be most effective at reducing diarrhea.

EXPECTED RESULTS

Preliminary field data have suggested that pathogen levels in household drinking water storage containers may be significantly higher than community water sources. This suggests that point-of-use water treatment interventions such as the introduction of household ceramic water filters might be the most beneficial. However, ABM modeling frequently reveals unexpected, emergent outcomes that could not have been predicted based on model inputs. Therefore, a full behavior space analysis will be conducted to search for such emergent outcomes.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The model can be an easy-to-use tool for researchers, government agencies and humanitarian organizations worldwide and will provide valuable insight into the complex pathogen transmission chain that leads to ECD. This insight will inform the development of intervention strategies that can be broadly applied to similar settings throughout the developing world.

Keywords: *diarrhea, agent-based modeling, ABM, coliform, water, sanitation, hygiene, Africa, health, transdisciplinary*

Innovative Investigations for Oil Spill Impacts

Emerging Environmental Approaches & Challenges: Innovative Investigations for Oil Spill Impacts
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EPA Project Officer: Brandon Jones
Project Period: 09/06/2011- 09/05/2014
Project Amount: $126,000
Environmental Discipline: Civil/Environmental Engineering

Jeff Shovlowsky Bowman

E

Potential for the Sea Ice Microbial Community to Bioremediate Crude Oil

Bio

Jeff Bowman earned his undergraduate degree in oceanography from the University of Washington. While there, he became interested in microbial persistence and growth in sea ice and other regions of the cryosphere. He earned his Master's studying the distribution of bacteria at the sea ice surface, work which took him to the north coast of Alaska and the North Pole. Currently, he is investigating the potential role of the sea ice microbial community in the bioremediation of crude oil.

Synopsis

Increasing oil exploration at high latitudes raises the risk of an oil release in ice covered seas. This research focuses on the potential for the sea ice microbial community to mitigate the effects of an oil release. For this investigation, an assessment of microbial community structure across the sea ice environment will be conducted and a search for genes involved in crude oil degradation.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This study has three objectives: (1) establish a baseline of microbial community structure and composition within sea ice, including members of the rare biosphere who may have bioremediation potential; (2) search for genes known to be involved in the degradation of crude oil within several different components of the sea ice environment; and (3) determine the prevalence of these genes within the active segment of the microbial community.

APPROACH

DNA will be extracted from samples of first year ice, young sea ice, marine water and surface ice features (known to be microbial enriched) from McMurdo Sound, Antarctica. Pending additional field opportunities, samples also may be collected from Barrow, Alaska or Nuuk, Greenland. Purified DNA from these samples will be amplified for the V6 hypervariable region of the 16S rRNA gene and sequenced in a massively parallel fashion using the paired-end technique on either the SOLiD or Illumina sequencing platforms. Both of these platforms support sufficient multiplexing to allow replication, yet still allow for great sequencing depth (tens of millions of reads per sample). Taxonomic and phylogenetic analysis of assembled paired-ends, and community description with standard ecological indices will establish a valuable baseline of the sea ice microbial community. Amplification of the purified DNA with primers specific to genes marking known pathways for the degradation of crude oil components, followed by clone library and T-RFLP analysis will characterize the bioremediation potential of the sea ice microbial community. Amplification of these same genes from sea ice microcosms labeled with heavy carbon substrates (stable isotope probing, or SIP) will determine to what extent these genes are contained within an active segment of the microbial community, and thus are available for rapid bioremediation.

EXPECTED RESULTS

Due to the concentrating effects of eutectic freezing, sea ice brines are considered to be an organic rich environment. Microbes adapted to life in sea ice should be capable of living under these conditions and degrading a wide range of organic compounds. Because of this, the expectation is to find that the sea ice microbial community is able to consume a broad range of organic compounds found in crude oil. If this is the case, then sea ice might serve as the seedbank for a community of oil degrading organisms in the case of an oil spill at high latitudes.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Increasing oil exploration in the Arctic, and the potential for exploration in the Antarctic, raise the risk of a release of crude oil in ice covered seas. This project provides valuable information on the potential of the sea ice microbial community to bioremediate released crude oil.

Keywords: *sea ice bacteria, bioremediation, stable isotope probing, Arctic oil exploration*

Emerging Environmental Approaches & Challenges: Innovative Investigations for Oil Spill Impacts
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Toxicology

Christine Renee Lattin

E

Evaluating the Stress Response of Wild Birds as a Bioindicator of Sub-Lethal Acute and Chronic Effects of Crude Oil Exposure

Bio

Christine Lattin received her B.A. in Linguistics from Swarthmore College in 2001. Over the next few years, she worked in science and education at Glen Helen Raptor Center in Ohio, Hawk Mountain Sanctuary in Pennsylvania, and Eloise Butler Wildflower Garden and Bird Sanctuary in Minnesota. She received her M.S. in Biology from Eastern Kentucky University in 2008, and started her Ph.D. at Tufts University in the fall of the same year. Her doctoral research focuses on the stress physiology of wild animals.

Synopsis

To successfully cope with challenges in their environment, wild animals must be able to mount a physiological stress response. Ingested petroleum can severely compromise this response in ways that are poorly understood. This project will examine both short- and long-term effects of petroleum on the stress response of wild birds, allowing us to evaluate whether the stress response could be used as a bioindicator of crude oil exposure in migratory and resident birds in the Gulf of Mexico.

OBJECTIVE(S)/RESEARCH QUESTION(S)

One of the most important yet least understood of oil's biological impacts is on the stress response. Studies show petroleum can interact in an additive fashion with other stressors to cause increased mortality, but it is not clear exactly why—does petroleum change stress hormone receptor concentrations in the brain or peripheral tissues, does it disrupt feedback mechanisms or stress hormone production, or both? This study uses both laboratory and field components to systematically quantify the effects of Gulf of Mexico crude oil on the stress response and stress hormone receptors of wild birds. This will allow an evaluation of whether these physiological measures can be used as bioindicators of sub-lethal acute and chronic effects of crude oil exposure.

APPROACH

This study proposes to clarify petroleum-induced changes to the hypothalamus-pituitary-adrenal (HPA) axis responsible for the release of glucocorticoid stress hormones. The study has three goals to: (1) determine what the HPA functioning of an oil-compromised bird looks like, including tissue concentrations of stress hormone receptors; (2) examine HPA functioning in birds both immediately after crude oil ingestion and several months later to look for long-term effects of oil exposure; and (3) compare the effects on the HPA of several different crude oils. The first stage of this project will take place in the laboratory, using wild-caught House Sparrows as a model species. The second stage of the project includes fieldwork in the Gulf of Mexico to determine if wild shorebirds fit expected profiles of oil-exposed animals, both in terms of HPA functioning and receptor concentrations.

EXPECTED RESULTS

By the project's end, there will be a much deeper understanding of how ingested petroleum impacts the stress response of wild birds, not just at the level of secreted hormone, but also upstream and downstream of the adrenal glands. The study will provide a better idea of how long to expect oil-induced disruptions to the HPA axis to last: will these effects persist 3 months, 6 months or a year later? Furthermore, based on differences in response to different crude oils, the study will be able to start to identify which components of petroleum do the most damage to the HPA axis. The strength of this project's approach is that it goes above and beyond just measuring stress hormone concentrations in the blood, and examines negative feedback mechanisms, maximal possible response and stress hormone receptors.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

A clearer understanding of petroleum's effects on wild birds is essential to help people better respond to oil spills and their aftermath (for example, better prioritization of sites to manage), and to fully understand the conservation impacts of these spills. This project could potentially also allow people not only to identify exposure in wild shorebirds from contaminated areas, but also in other species, including humans.

Keywords: *stress, hypothalamus-pituitary-adrenal axis, avian physiology, shorebirds, bioindicators, petroleum, toxicity, oil spills*

Emerging Environmental Approaches & Challenges: Innovative Investigations for Oil Spill Impacts
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Chemistry

John William McIlroy

E

Objective Decision-Making Tools for Modeling the Fate of Complex Petroleum Products in the Environment

Bio

John McIlroy is currently a graduate student at Michigan State University, working on his Ph.D. degree in Analytical Chemistry and an M.S. degree in Forensic Chemistry. His doctoral research focus is on modeling the environmental weathering of petroleum products, using multivariate statistics. He earned his undergraduate degrees in Biochemistry, Forensic Science and Application of Science and Law from Mercyhurst College, in Erie, Pennsylvania in 2005. He is originally from Huntingdon, Pennsylvania.

Synopsis

Recent events have highlighted the environmental hazards of petroleum discharges and the knowledge gaps that hinder risk assessment and remediation. Part of the challenge in assessing discharges is the complexity of the sample and the changes in the physical and chemical properties that occur due to weathering processes. This project will develop models to describe the weathering processes that will aid in decision-making and the prediction of the environmental fate of the petroleum products.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The oil spill in the Gulf of Mexico has highlighted the environmental hazards of petroleum discharges and the knowledge gaps that hinder accurate risk assessment and remediation. Part of the challenge in assessing petroleum discharges is the complexity of the sample and the changes in the physical and chemical properties that occur due to weathering processes. Improvements in the fundamental understanding of these transport processes promise to improve impact assessments of discharges and to test remediation effectiveness. The proposed research aims to develop empirical rate constants for relevant physical and chemical weathering processes to serve as the foundation for models of fate of petroleum and biofuel constituents.

APPROACH

Diesel fuels will serve as an example of a complex pollutant mixture. The fuel samples will undergo four different simulated weathering processes: evaporation, photooxidation, hydrolysis and microbial degradation. These weathering processes were chosen to closely simulate a spill on water, but the methodology and results can be expanded to other environments as well. The chemical changes will be monitored over time, using both gas and liquid chromatography with mass spectrometry. Multivariate statistical techniques will be applied to identify the components that are changing during each of the weathering processes. These components will then be modeled to predict rates of degradation or formation. The model will be developed for constituents with well-defined physical parameters, and then extended to other constituents with similar chemical properties. This will provide the kinetic information for the determination of the rate constants and reaction orders. The final model will consist of an array of rate constants and reaction orders for individual compounds as well as classes of chemical compounds, such as alkanes, alkyl benzenes and polycyclic aromatic hydrocarbons (PAHs).

EXPECTED RESULTS

The proposed research will provide a comprehensive model that can predict the loss and formation of compounds as a result of weathering of petroleum products. This will build on past models by modeling not only individual compounds, but also by modeling classes of compounds. As a result, a more comprehensive model that takes into account the properties of the bulk mixture will be developed. In addition, multivariate statistical procedures will be applied to help identify the relevant sources of variation between samples. Evaporative loss is expected to be the dominant weathering process, and potentially mask changes from the other weathering processes. By modeling each weathering process individually, it will be possible to correct and minimize the masking that may occur. The model can be used to guide decision-making, as it will predict the loss or formation of compounds. Toxic compounds, such as PAHs, are of particular interest, due to their toxicity and potential reactions that may occur during photooxidation. The model also can be used to evaluate the effectiveness of remediation procedures. Successful remediation procedures will remove constituents faster than the model predicts. Finally, the model can be used to derive the original composition of the petroleum product, based on predicted weathering processes. This would then allow for the comparison of fuels to determine responsibility or origin of the pollution.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research will provide a more comprehensive understanding of the compounds that are present at a petroleum spill site. In addition, it will allow for the prediction of newly formed compounds. A more complete understanding of the weathering processes will help to direct cleanup efforts and provide a better estimation of the long-term effects of a petroleum spill. Prediction of the degradation processes that are occurring also may lead to targeted remediation, lessen the economic impact and better assist relief organizations in strategic planning.

Keywords: *environmental fate, weathering, petroleum fuel, biofuel, environmental modeling*

Social Sciences

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Social Sciences

Wylie Allen Carr

E

Managing Sunlight: Exploring Underrepresented Populations' Perspectives on Geoengineering

Bio

Wylie Carr received his undergraduate degree in Religious Studies from the University of Virginia in 2006. After moving to Missoula, Montana the following year, he discovered a passion for environmental issues, with a particular interest in the social aspects of climate change, and enrolled in the College of Forestry at the University of Montana. Wylie conducted research on the relationship between theologically conservative Christians' religious beliefs and their views on climate change for his Master's thesis, which he completed in May 2010. He began a Ph.D. program in the same department at the University of Montana in August 2010, but spent half of the past year in the United Kingdom as a visiting student at Lancaster University's Sociology Department. His current research is focused on the social and ethical questions raised by geoengineering.

Synopsis

This research will examine opportunities for expanding public dialog about geoengineering to include broader cultural perspectives. It will utilize qualitative social science data to investigate how publics that may be disproportionately impacted feel about various geoengineering proposals. With an understanding of more diverse perspectives, this research will be able to point towards more inclusive, transparent and democratic modes of public engagement on geoengineering in the future.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research will examine opportunities for expanding public dialog about geoengineering to include broader cultural perspectives. The two primary research questions are: (1) How do populations that are currently underrepresented in discussions about geoengineering, but who may be significantly impacted by various geoengineering research or deployment proposals, feel about geoengineering? (2) How could such populations be more effectively included in future discussions about geoengineering research and governance?

APPROACH

This research will utilize qualitative social science data to answer the primary research questions. Data collection will include indepth interviews and participant observation. Research participants will be selected from regions both within and outside of the United States that current climate models indicate may be significantly impacted by various geoengineering proposals. Data analysis will be informed by sociological theory, more specifically a science and technology studies perspective.

EXPECTED RESULTS

The results of this research will point towards more inclusive, transparent and democratic modes of public engagement on geoengineering. By incorporating geographically and culturally diverse perspectives, this research will indicate concerns related to geoengineering that have not yet been raised or recognized. This research also will indicate how certain populations that will possibly be significantly impacted by geoengineering can be more effectively included in future discussions about geoengineering research and governance.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Geoengineering proposals are predominately global in scale, meaning that they have potentially wide ranging impacts on both environmental and human health. Various geoengineering proposals may help to lessen potentially severe impacts from climate change; however, many of the potential impacts to the environment and human health from geoengineering currently are unknown. Additionally, current discussions about geoengineering are primarily limited to scientists and politicians in wealthy, developed nations. This research project is designed to help broaden the discussion about the potential impacts of geoengineering on both human and environmental health to include more diverse perspectives. By diversifying the discussion, this research has the potential to make geoengineering efforts aimed at protecting environmental and human health more transparent and democratic.

Keywords: *geoengineering, qualitative social science, public engagement*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Social Sciences

Brian Christopher Chaffin

E

Coordinating Collaboration for Improved Water Quality in the Klamath Basin, USA: Toward a Model of Adaptive Governance

Bio

Brian Chaffin holds a B.S. from the Department of Conservation Social Sciences and an M.S. from the Department of Environmental Science at the University of Idaho. His previous graduate research investigated the institutional organization of state-based watershed groups in the Pacific Northwest. Brian enjoys work and research in rural watersheds and has worked many seasons as a commercial wilderness river guide. His Ph.D. research at Oregon State University focuses on the recently proposed Klamath River Basin Restoration Agreement and implications for improved basin water quality.

Synopsis

A growing number of bottom-up approaches to water quality governance have emerged from collaborations of community leaders sensing the need for alternatives to top-down water quality regulation. This project analyzes institutional arrangements for managing water quality in the Klamath River Basin of Oregon and California. Recent collaborative agreements forged by Klamath Basin stakeholder groups may offer innovative solutions for coordinating water quality improvements at the basin scale.

OBJECTIVE(S)/RESEARCH QUESTION(S)

In recent years, a growing number of bottom-up approaches to water quality governance have emerged from groups of local actors, social networks and various collaborations of community leaders sensing the need for alternatives to top-down government through new approaches to environmental decision making. These efforts have been largely successful, specifically in the context of ecological restoration for improved water quality. The question arises: Can multiple, locally based, collaborative efforts to improve water quality be coordinated across a large-scale ecosystem such as a large river basin?

APPROACH

The institutional arrangements in the Klamath River Basin of south-central Oregon and northern California present an optimal case study area to test the coordination of collaborative efforts to improve basin water quality. Through the theoretical framework of adaptive governance, this study will test the hypothesis that collaborative agreements forged between Klamath River Basin stakeholder groups provide the framework necessary to coordinate multiple collaborative water quality improvement efforts. At the core of the proposed project is an indepth elucidation and analysis of the key features of the Klamath Basin Restoration Agreement (KBRA) and its companion Klamath Hydroelectric Settlement Agreement (KHSA), which together, comprise one of the most comprehensive ecosystem restoration projects ever envisioned. Further research techniques will include an institutional mapping exercise to identify and characterize existing approaches to water quality management in the Klamath Basin, as well as semi-structured interviews with representatives from federal, state and tribal agencies associated with Klamath water quality governance.

EXPECTED RESULTS

The data from interviews and document analyses may suggest that the KBRA contains a number of innovative solutions to the problem of identifying a governance mechanism to unite individual collaborative efforts to improve basin water quality. Research on the Klamath agreements will be used to contribute a framework of adaptive governance to the theoretical and applied literature, including an analysis of lessons learned, practical limitations and guidelines for implementing adaptive governance to unify collaboration. The Klamath case study will satisfy a broader need for on-the-ground examples of adaptive and collaborative governance with the potential to improve water quality in a variety of geographic scales and contexts.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research explores a case study of coordinating collaboration as a framework for improving water quality and achieving the goals of the Clean Water Act. This research will contribute to existing knowledge and scholarship on the potential promise of emerging forms of devolved environmental governance aimed at ecological restoration for the improvement and protection of water quality. Innovative agreements represent future solutions for improving water quality through the coordination of individual collaborative initiatives, while at the same time serving the needs of resource dependent stakeholders, complying with regulatory requirements, and reducing conflict over rural water.

Keywords: *adaptive governance, collaborative management, water quality, Klamath River, Clean Water Act*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Economics

Jeffrey Chow

E

Quantifying Local Benefits of Mangrove Plantation Shelterbelt in Coastal Bangladesh

Bio

Jeffrey Chow is a doctoral candidate studying natural resource and environmental economics at the Yale School of Forestry and Environmental Studies. His research focuses on the economics of land use at the interface of agriculture and forests within tropical, developing regions. Previously, Jeff worked at Resources for the Future, an environmental economics and policy think tank in Washington, D.C. He holds Master of Environmental Management and Master of Forestry degrees from the Duke University Nicholas School of the Environment, and a B.S. in Biology from Arizona State University.

Synopsis

Mangroves can provide a wide range of goods and services, such as protection for inland areas during tropical storms. Bangladesh has established over 160,000 hectares of coastal mangrove plantations due to its vulnerability to cyclones. Utilizing surveys of coastal villagers, this project investigates the local economic value of these plantations derived from direct uses. This study also uses GIS-aided econometric analyses to look for evidence that mangrove plantations reduce damages from storm surges.

OBJECTIVE(S)/RESEARCH QUESTION(S)

(1) What direct uses do mangrove plantations provide to rural coastal communities? (2) How do benefits from mangrove plantations contrast to those from natural mangroves? (3) Based on socioeconomic and geophysical data, is there evidence that mangroves mitigate economic damages associated with storm surge?

APPROACH

To answer the first question, this study conducts structured interviews with coastal villagers to determine the extent of direct local use. Secondly, this study reviews and updates a forest valuation exercise undertaken for the Sundarbans Reserve Forest, a natural mangrove forest in Bangladesh, by the Food and Agriculture Organization of the United Nations (FAO). Addressing the third question, this study employs a modified Ricardian analysis to investigate whether mangrove plantations impart protective benefits that materialize as gains in farm net revenues. This study focuses on the economic impacts of a mangrove plantation rather than mortality effects because the development of shelters and early warning systems continually will reduce the loss of life due to tropical storms in the long run. Agricultural and aquacultural production would remain vulnerable, however, and would require protection via man-made defenses. Finally, quantification of economic benefits allows calculation of benefit-cost ratios using data on plantation management costs.

EXPECTED RESULTS

The initial surveys undertaken suggest that village use of the mangrove plantations may be meager. Local uses include fuelwood harvest, animal fodder collection, fruit collection and recreation. Because the plantations are largely monocultures that also lack the extensive networks of streams characteristic of the Sundarbans, a natural mangrove ecosystem, it is expected that direct use of plantations is largely confined to fuelwood collection. Consequently, the diversity and value of direct uses associated with natural mangroves would exceed those of the plantations. This study models mangrove coverage in three ways: presence or absence of mangrove vegetation between the farm and the coast; the width of mangrove vegetation between the farm and the coast; and the total impedance generated by mangrove vegetation. The parameters associated with each specification can be interpreted respectively as the marginal effects of mangrove presence, mangrove width and total mangrove resistance on net revenues. These three variables are expected to have a positive relationship with net farm revenues because all three variables represent greater impedance to storm surges traveling inland, and because net revenues are expected to be inversely related to storm surge vulnerability. The econometric analysis is more likely to discern significant effects from the 2000 dataset than the 2005 dataset due to greater storm activity in 2000. Other specifications will be explored as this project progresses.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Socioeconomic, geographical and climatic characteristics make Bangladesh one of the countries most sensitive to the damaging impacts of climate change. The country's low topography, underdevelopment and heavy reliance on agriculture make it especially vulnerable. Rises in sea-level and sea surface temperatures will lead to greater intensity of tropical storms, threatening poor households, coastal infrastructure and agricultural productivity. The Reduction of Climate Change Hazards through Coastal Afforestation with Community Participation is Bangladesh's top priority climate adaptation project. Its primary objective is to create a thick coastal forest belt to stabilize shorelines, reduce storm surges and prevent soil salination. However, if mangrove plantations are less effective at protection than expected, they may create a false sense of security and put more lives and property at risk. By shedding light on the current socioeconomic impact of previous efforts in Bangladesh, this research will inform this and other mangrove plantation initiatives, such as those in Indonesia, Thailand and Vietnam, which are now underway as a response to expected climate change.

Keywords: *valuation, agriculture, mangroves, ecosystem goods and services, Bangladesh*

Emerging Environmental Approaches & Challenges: Social Sciences
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EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Anthropology

Abigail Elizabeth Conrad

E

Permaculture Gardens: Investigating Food Security and Alternative Agriculture Among Smallholder Farmers in Malawi

Bio

Abigail Conrad completed a B.A. in Anthropology at the University of Rochester in 2008. She is currently a Ph.D. candidate in Anthropology at American University in Washington, D.C. Her research focuses on livelihoods, agriculture and food security in Malawi, where she completed preliminary research in 2008 and 2010. She will conduct her dissertation research in Malawi on the relationship between the alternative agricultural practice of permaculture, and food and nutrition security.

Synopsis

This study explores food security and permaculture among smallholder farmers in Malawi. Small-scale farming to meet food and livelihood needs is a central activity for households in rural Malawi. Permaculture is a low-input ecological design and alternative agricultural system. Given the sociocultural, economic and environmental constraints to permaculture adoption, this study will investigate if smallholder farmers can use permaculture to improve household food security.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The central research question for this study asks: Given the cultural and structural constraints to the implementation and adoption of permaculture agricultural practices, can smallholder farmers use permaculture to improve their household food security? Further, this study will explore how individuals' perceptions of agricultural production, food consumption, food security and nutrition both shape, and are changed by, permaculture implementation.

APPROACH

This study will research three permaculture programs in Malawi and evaluate their impact on the food security of participating smallholder farmers. The study will use ethnographic research methods, and food and nutrition security measures to determine the impact that involvement in permaculture programs has on households. Research will be conducted with both farmers involved in permaculture, and with farmers not involved in permaculture, to compare their food security and food production practices. Nongovernmental organization (NGO) programs that use different permaculture outreach and teaching techniques, implementation methods and NGO types will be examined to determine how these different approaches to permaculture impact its adoption and participants' food security. Further, this study will explore how individuals' perceptions of agricultural production, food consumption, food security and nutrition both shape, and are changed by, permaculture implementation.

EXPECTED RESULTS

Empirically, this project will contribute to existing literature through needed ethnographic documentation of the implementation of permaculture, and its impact on food security, the environment and nutrition, and food consumption practices. Using ethnographic methods and food and nutrition security measures, this study will research and analyze the benefits and limitations of using permaculture as a sustainable agricultural and diet-based or food-systems intervention to improve nutrition and environmental health. In addition, this study will contribute to the knowledge of how the relationships between alternative agriculture practices and structural constraints, and food consumption preferences and practices, impact food security and nutrition.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This project will contribute relevant and important information to the debate about the impact of agricultural production techniques on food security and nutrition. This research also will directly address the negative interactions between the problems of food insecurity and health. If this study finds that farmers can overcome the structural barriers to changing agricultural production and adopt permaculture, and that permaculture improves food security, then the results would be significant for national policies and development projects far beyond the programs studied. Permaculture programs, with their flexible design system, might then be scaled-up to neighboring countries in the regions that face similar problems.

Keywords: *food security, permaculture, alternative agriculture, livelihoods*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 9/1/2011 - 6/31/2015
Project Amount: $126,000
Environmental Discipline: Anthropology

Lauren Nicole Coyle

Dual Sovereignties in the Golden Twilight: Law, Land and Environmental Politics in Ghana

E

Bio

Lauren Coyle is a doctoral student in Anthropology at the University of Chicago, where she works broadly at the intersections of law, kinship, environmental politics, postcolonial sovereignty, critical development theory and historical ethnography, particularly in Ghana. She received a J.D. from Harvard Law School in 2008, having begun work on environmental justice issues in Ghana with the local Friends of the Earth chapter, under a Harvard Human Rights Summer Fellowship in 2007. Her ongoing legal and anthropological research has been supported by several sources, including the American Philosophical Society, Some Institutes for Advanced Study (SIAS), Social Science Research Council, Wenner-Gren Foundation for Anthropological Research, West African Research Association, Land Deal Politics Initiative and Lincoln Institute of Land Policy.

Synopsis

How does the colonial legacy of two parallel legal systems interact with various shadow sovereigns to frame postcolonial nationhood in Ghana? This study hypothesizes that the recent flourishing of "rule of law" governance programs has rendered this dual legal legacy a critical register of tensions and aspirations in postcolonial citizenship, sovereign government and kin-based belonging. Gold mining is perhaps the most significant site of contests fought under the dual legal legacy of colonialism, as multiple entities seek to benefit from its yield. Those contests, therefore, serve as the focus of the project. This study involves conducting ethnographic research centered in the mining town of Obuasi, and also extends to villages near Tarkwa and Kenyasi, as these are the areas most affected by surface mining. Archival research also is being conducted in the United Kingdom and Ghana.

OBJECTIVE(S)/RESEARCH QUESTION(S)

How does the colonial legacy of two parallel legal systems—one "customary," the other under the jurisdiction of the state—frame postcolonial nationhood in Ghana? How, in particular, does it frame the often violent conflicts over property regimes that govern the ownership and extraction of resources in its neoliberal economy? How has this legacy assumed new meaning and heightened significance for environmental politics in the wake of structural adjustment reforms in Ghana? This study hypothesizes that the recent flourishing of "rule of law" governance programs has rendered this legal legacy a critical register of tensions and aspirations in postcolonial citizenship, sovereign government and kin-based belonging, and in counterintuitive ways that resonate across contemporary Africa that remain largely underexamined in most of the relevant literature.

APPROACH

Gold mining, Ghana's most lucrative extractive industry, is perhaps the most significant site of contests over land and environmental justice fought under the dual legal legacy of colonialism, as indigenous peoples, traditional authorities, corporations and the state seek to benefit from its yield. Those contests, therefore, will be the focus of the project. Ethnographic research will be conducted through interviews, focus groups and observation of various ritual, political and legal proceedings in "customary" and "state" domains. Research will be centered in villages in Tarkwa (Western Region), Kenyasi (Brong-Ahafo Region) and Obuasi (Asante Region), the three areas most affected by surface-mining and all home to groups that fall within the canopy ethnic group of the Akan. In addition, interviews will be conducted and proceedings observed in civil society groups concerned with mining, land and labor (especially those housed in a consortium of prominent NGOs, the National Coalition on Mining [NCOM]), along with relevant state and customary governmental bodies—principally, commissions and courts. Lastly, archival research will be conducted in the United Kingdom (colonial and mining company archives) and Ghana (colonial, national and customary kingdom archives).

EXPECTED RESULTS

Through this ethnographic and archival research, the development of mining and related disputes over labor, resources, environment and land will be traced. This ethnographic research will allow for nuanced analysis of how "environmental justice" functions as a key domain for political contests under Ghana's neoliberal "rule of law" programs, which privilege the legal domains of contracts, constitutions and courts over, for example, state legislation and administrative functioning. This historical research will allow for analysis of the development of the present-day dual legal system under the British project of "native administration," including colonial systematization and even invention of customary law, as it spread throughout the coastal Gold Coast Colony and Asante Kingdom territory to the North. In addition, archival work will allow a fuller understanding of transformations in extraction and the dual legal system throughout the early years of independence and the ensuing decades under modernizing, developmentalist regimes, and then into the structural adjustment reforms of the 1980s.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Overall, this research will illuminate ways in which various phases of modernist governance formations—colonial, state-developmental and neoliberal—have articulated with, on the one hand, global phases of international law and raw resource extraction and, on the other, "customary," kin-based systems of politics, labor and land tenure in colonial and postcolonial settings. This will enhance analysis of the perils and prospects of environmental justice and public health initiatives in current neoliberal development programs, particularly as they operate in resource-rich postcolonial settings where both customary and state authorities serve as key components of the constitutional order.

Keywords: *environmental politics, mining and labor, kinship, customary v. state law, land conflicts, postcolonial sovereignty, neoliberal governance, Ghana*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Probability/Statistics

Gregory George Garner

E

Statistical Post-Processing of the National Air Quality Forecast Capability to Optimize the Value and Layout of Ozone Monitors in the Washington-Baltimore Region

Bio

An alumnus of the Boston Latin School, Gregory Garner graduated *cum laude* from Plymouth State University in 2006 with a B.S. in Meteorology and an M.S. in Applied Meteorology in 2007. He taught "Introduction to Weather," a science general-education course, as an adjunct faculty member at Plymouth State University in the spring semester of 2008. He joined an air quality research group at Pennsylvania State University in the fall of 2008, where he is currently working on his Ph.D. in Meteorology. He is also a member of the American Meteorological Society (2003) and Mensa (2006).

Synopsis

Air shed managers often rely on the national air quality computer model to make informed decisions regarding pollution actions and policy in their region. This project will apply statistical post-processing to this model, similar to what is done with weather models, to improve the skill and economic value of the forecasts. These improved forecasts also will be used to optimize pollutant monitor layout in the Baltimore-D.C. region.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Air shed managers rely on accurate air quality forecasts when making decisions regarding actions and policy on pollution emissions and exposure in their region. The National Air Quality Forecast Capability (NAQFC) produces these forecasts; however, there are known problems with this model. This project will apply statistical post-processing algorithms known as Model Output Statistics (MOS) to the NAQFC, similar to what is done with meteorological models, to improve the forecast skill and economic value. These algorithms then will be used to optimize pollutant monitor layout in the Washington-Baltimore area.

APPROACH

Observed and forecasted 8-hour surface ozone mixing ratios, along with various meteorological and chronological variables, will be assembled from the Washington-Baltimore region during the ozone seasons (April-October) of 2005 through 2010. These data will be used to train Classification and Regression Tree (CART) models for each monitor in the region. The CART models are trained by recursively splitting the observed ozone into homogeneous groups depending on the state of the included variables. A multivariate regression model will be fit to each group. This process will be repeated numerous times using a bootstrap process. This process produces a distribution of possible outcomes with the mode of the distribution yielding the forecast conditioned on known local statistical relationships. The resulting CART and regression models are the MOS for the given monitor. Cross-validation will be used to assess the error of the MOS forecasts. These MOS can then be applied to methods in determining optimal monitor layout using spatial correlation and value metrics.

EXPECTED RESULTS

The product resulting from this research will be a robust tool for forecasting ozone events in the Washington-Baltimore region. The increased skill of these forecasts will provide sound information to decision makers regarding actions and policy that reduce emission of and exposure to pollutants. The additional value produced by these forecasts will provide quantifiable evidence of how these decisions affect the local economy. By applying these MOS to methods of optimizing pollutant monitor layout, maximum data quality can be attained with minimum cost.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

By increasing forecast skill, decision makers can have higher confidence in their choices to mitigate emissions and exposure. This will minimize human health problems and environmental impacts related to exposure to poor air quality events while maximizing resource efficiency.

Keywords: *air quality, forecasting, modeling, decisions, decisions under uncertainty, model output statistics, MOS, regression tree, CART, bootstrap, cross-validation, value*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Geography

Joseph Hamilton Hoover

E

Investigating the Utility of Web-Based GIS in Water Quality Environmental Decision-Making

Bio

Joseph Hoover earned an undergraduate degree in Environmental Sciences, specializing in Environmental Chemistry, from Northwestern University in 2007, and a Master's degree in Geography, specializing in Water Resources, from the University of Arizona in 2009. He is currently a doctoral student in Geography at the University of Denver. His research is situated at the intersection of environmental water resources decision-making and the role of web-based geographic information science applications.

Synopsis

Effective water resources decision-making requires stakeholder participation, which can be challenging because of technical language in scientific reports. The research objectives are to investigate the utility of web-based GIS applications to help researchers and environmental NGOs convey scientific information about groundwater quality to stakeholder groups, analyze participant perceptions of a web-based application and clarify the role of web-based technology in environmental decision-making.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The purpose of this study is to examine the effectiveness of a web-based Geographic Information System (GIS) in facilitating communication between stakeholders and non-governmental organizations and institutions of higher education researchers. It will evaluate the potential of webGIS as a tool to increase stakeholder participation in environmental decision-making for water resource issues.

APPROACH

This study will employ a mixed methods research design to: (1) gather, evaluate and analyze user perceptions toward the effectiveness of the web tool to convey scientific information and policy scenarios; (2) evaluate perceptions toward the scope and depth of human health impacts from drinking water contamination; (3) assess the applicability of the web-based geovisualization tool in environmental decision-making; and (4) determine user attitudes regarding the web-based geovisualization tool. Data collection, summarization and analysis procedures include descriptive statistics, survey coding, ANOVA, Q method and factor analysis.

EXPECTED RESULTS

The expected project results will provide researchers and practitioners a contemporary technological model for providing enhanced interactive web-based presentations leading to more effective stakeholder participation in the environmental decision-making process for water quality and water resource issues. To this end, the general public can become more involved in the environmental decision-making process leading to more effective environmental policies.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Project results will enable policy makers and researchers to more effectively communicate scientific information regarding groundwater contamination to stakeholders. As a result, greater stakeholder participation will lead to better human and environmental protection because environmental decision-making will be more effective.

Keywords: *water resources, webGIS, environmental decision making, groundwater quality*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 08/31/2011 - 08/30/2014
Project Amount: $ 126,000
Environmental Discipline: Chemical Engineering

Jordan Patterson Howell

E

Beyond the Technical: Innovative Approaches to Understanding Implementation of Waste-to-Energy in the United States

Bio

Jordan Howell earned his undergraduate degree in Anthropology from the College of William and Mary in 2008. He started his graduate training in Geography at Michigan State University that same year, completing his Master's degree in 2010 and shortly thereafter beginning the Ph.D. program. His research focuses on historical and cultural dimensions of the human-environment relationship, and pays special attention to energy issues and the changing role of technology in society.

Synopsis

Landfilling and electricity generation have harsh side effects like air pollution, groundwater contamination and landscape destruction. Modern solid waste incinerators circumvent these concerns, but the use of this technology remains minimal in the United States. This project considers the social and cultural reasons for this limitation, critically examining the attitudes, motives, tactics and networks mobilized to both deploy and resist the deployment of modern solid waste incinerators.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Americans are landfilling more garbage than ever before while simultaneously consuming increasing amounts of electricity generated by fossil fuels; both activities have negative environmental and human health side effects. Modern solid waste incinerators (waste-to-energy, or WtE, incinerators) can preclude many of these harmful effects, but the deployment of this technology remains very limited in the United States. This research project examines the social and cultural foundations for such reluctance, contributing directly to the understanding of the ways in which technologies with significant environmental impacts succeed or fail.

APPROACH

This study will examine the published and unpublished statements, papers, project studies, policy briefs and archival materials generated by and about the development of WtE facilities in the United States, focusing on both specific case studies and WtE technology in general. The study also will analyze legal documents, laws and news media representations of WtE along with the records of environmental and industry interest groups. In addition to these written sources, other "texts" related to WtE will be studied, including films, websites, signage and logos, advertising campaigns, facility architecture, artwork, music and sounds, along with more abstract "texts" like conferences, trade shows and academic and industry research programs. From these raw materials, this study will build on the insights of actor-network theory and discourse analysis to map (both literally and figuratively) the arguments involved in both promoting and resisting the deployment of WtE facilities in the United States.

EXPECTED RESULTS

Preliminary research suggests that limits to the deployment of WtE technology hinge on continuing public fear over incinerator emissions and by-products, incineration's "low-tech" image and economic disincentives for project development. These challenges have less to do with WtE technology itself than with public perceptions of it, perceptions that exist because competing entities (pro-/anti-WtE) have mobilized various resources (scientific papers, agencies, images, fear, "the environment," solid waste) in the construction and extension of their own positions (for or against WtE plants) and thereby projected power over both physical and ideological space (whether WtE plants are built; what people think of them). Describing and mapping (both literally and figuratively) these constructions represents the crux of this research, and as such the project will produce not only an empirical study of WtE technology in the United States, but also a framework for analyzing other problems lying at the intersection of the environment, human health and technology.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This project aids in the understanding of the factors that influence the deployment and public acceptance of technologies with significant environmental impacts. Although this research deals directly with WtE, it functions also as a more general framework for moving beyond "technical" and "hard science" research in the environmental protection arena, and contributes to a model of greater diversity in community and environmental planning.

Keywords: *incineration, waste-to-energy, technology, geography, science and technology studies, social science, energy*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Geology (Hydrology)

Freyja Liselle Knapp

E

Mining for Gold to Save the Environment? The Political Ecology of Global e-Waste Recycling

Bio

Freyja Knapp is currently a doctoral student in the Department of Environmental Science, Policy and Management at the University of California (UC), Berkeley. Her first career was as an ironworker, during which she advocated for women pursuing careers in the trades. She left blue-collar work and first earned a B.A. in Public Health with High Distinction, followed by an M.L.A. in Environmental Planning from UC Berkeley. She currently is researching the politics and use of science in international efforts to govern electronic wastes. Her research interests lie at the multiple intersections of political ecology, environmental health sciences, science and technology studies, globalization, environmental governance and international development.

Synopsis

Discarded electronic consumer goods, e-waste, has become a significant concern within the international environmental community due to its extreme toxicity and uneven geographies of environmental burden.

Contemporary approaches to governing e-waste in developing countries use a public-private partnership model. This project will critically examine how complex agendas and goals from corporate, environmental, government and public stakeholders intersect and exert influence within the context of global environmental problem-solving efforts.

This study offers a unique and informative case study that bridges environmental health sciences, environmental social sciences, international relations, global governance and policy studies, thus contributing key lessons for multi-stakeholder partnerships addressing complex socio-environmental problems.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Discarded electronic consumer goods, e-waste, has become a significant concern within the international environmental community due to its extreme toxicity and uneven geographies of environmental burden. Contemporary approaches to governing e-waste in developing countries use a public-private partnership model. This project will critically examine how complex agendas and goals from corporate, environmental, government and public stakeholders intersect and exert influence within the context of global environmental problem-solving efforts. This study offers a unique and informative case study that bridges environmental health sciences, environmental social sciences, international relations, global governance and policy studies, thus contributing key lessons for multi-stakeholder partnerships addressing complex socio-environmental problems.

APPROACH

E-waste, containing both toxic chemicals and precious metals, is a complex hybrid of hazard and commodity. This presents significant institutional challenges for the global and on-the-ground governance of e-waste and requires a social science approach. This project applies a political ecology framework that will explicitly address the physical, political and socio-economic dynamics of e-waste science, e-waste trade and "commodity production" to examine the relationship between the hazard-commodity nature of e-waste and the challenges of international environmental governance. The study will take a critical ethnographic approach in examining the processes at work and discourses leveraged in international environmental decision-making.

EXPECTED RESULTS

The problems of e-waste are made complex by the overlapping issues of environmental health, technology, labor, poverty, international trade and globalization. The strength of a political ecology framework is that all of these intersecting aspects of e-waste are explicitly addressed through analyses of the production and use of science, the physical and social origins of the e-waste problem and the multifaceted impacts of global e-waste flows. This research project will provide a nuanced investigation into the distribution of benefits and costs of e-waste "mining" across multiple and interrelated scales. It will address a critical research gap, both in e-waste studies, and in the international environmental governance literature, by focusing on the emergence and effectiveness of public-private partnerships at addressing complex environmental problems while balancing public goods and private profits.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

As the public-private partnership model of environmental problem-solving continues to grow in popularity, studies examining the performance of such an approach are critical for producing sustainable solutions to pressing environmental concerns. If multi-stakeholder processes do not adequately address the constellation of needs and interests among the diverse players, results may be modest at best. This study will illuminate how solutions are constructed in this type of partnership, providing key lessons for future public-private collaborations.

Keywords: *environmental health, public-private partnership, e-waste, hazardous waste, mining, precious metals, international development, science studies*

Emerging Environmental Approaches & Challenges: Social Sciences
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EPA Project Officer: Jose Zambrana
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental and Water Science

Morgan C. Levy

A Social-Ecological Study of Agricultural Water Management

E

Bio

Morgan Levy is a Master's/Ph.D. student at the University of California, Berkeley in the Energy and Resources Group. She received her B.A. from Sarah Lawrence College in New York. Prior to entering graduate school, she was a Fulbright Scholar in The Netherlands, comparing Dutch and California agricultural water management, and worked in the Water Program of the Natural Resources Defense Council. She is currently an intern with the Pacific Institute's Water and Sustainability Program. Her research focuses on agricultural water use and climate change impacts to freshwater resources.

Synopsis

To address a gap in understanding of agricultural water use in California, this research will integrate social and environmental hydrodynamic factors with a regional case study of the agricultural Sacramento-San Joaquin River Delta. Synthesis of quantitative plus qualitative information on irrigation will demonstrate how qualitative factors problematize the accuracy of water use measurement, and will contribute to the creation of a social-environmental process model for water resources research.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Eighty percent of California's freshwater supply is used for agriculture. However, unlike metered urban water, agricultural water use quantities are historically unrecorded, and irrigation practices are not well understood by those outside the agriculture community. Hydrologic processes such as evapo-transpiration and return flows complicate irrigation accounting. Yet, detailed information about irrigation is critical to better safeguarding freshwater supplies. To what degree on-farm decisions impact the reliability of information about water supply and quality is largely unknown. Researching this problem requires a human-environmental systems approach.

APPROACH

To address the gap in understanding of agricultural water use, this study will integrate social and environmental hydrodynamic factors with a regional case study of California's agricultural Sacramento-San Joaquin River Delta through original, interdisciplinary research. California is a model water-scarce region, where water issues center on the Delta, which supplies water for nearly half of the state's farms, and supplements a majority of state drinking water. The study will collect available quantitative water use information, and supplement that with original qualitative social systems research. The study will determine which qualitative factors significantly influence quantitative accuracy, and to what degree and larger impact.

EXPECTED RESULTS

An indepth review of quantitative plus qualitative information on water use will uncover significant unknowns about agricultural water use practices, showing that qualitative factors problematize the accuracy of reported water use measurement. This study will contribute unique water resources focused research to emerging scholarship on coupled human-environmental systems, creating the framework for a new social-environmental process model for water resources research.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The research will aid in the assessment of Delta ecosystem health as a whole, inform ecosystem-linked water supply decisions elsewhere, and serve as a model for proactive collaborations between diverse stakeholders on matters of water management that sustain and protect food supplies, drinking water, jobs and the environment. Water resources challenges require new modeling schemes that incorporate social-environmental interactions, while remaining accessible to policymakers and the public alike. This research will provide an alternative to simplistic bullet-point recommendations that do not adequately address complex systems.

Keywords: *fresh water resources, water management, agriculture, irrigation, California*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Geography

Wendy Beth Miles

Revaluing Rainforests: The Political Ecology of Neoliberal Conservation

E

Bio

Wendy Miles holds a B.S. in Environmental Studies from Evergreen State College and an M.S. in Biodiversity Conservation and Management from Oxford University. Prior to beginning her doctoral studies at the University of Hawaii, Wendy was the Associate Director of the North Coast Land Conservancy. She has been the recipient of the Ann Dunham Soetoro Award, Fulbright-IIE and East-West Center Fellowships. Her research focuses on the political ecology of environmental conservation and climate change mitigation.

Synopsis

A key design element of the proposed international carbon market is the commodification of CO_2 sequestered by forests. What will be the social ramifications of assigning economic value to forest ecosystem services? The proposed research addresses this through a case study of REDD+ that investigates: (1) the varying values designated to forests and how these are influenced by commodification and (2) the socio-economic impacts of commoditizing CO_2 on forest-dependent communities in Indonesia.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The objective of this research is to understand better the social ramifications of assigning economic value to forest ecosystem services. Through a case study of Reducing Emissions from Deforestation and Forest Degradation (REDD) in Indonesia, this study questions how people's forest perspectives are influenced by the commodification of carbon, to what extent forest-dependent communities are represented in REDD deliberations, and the potential socio-economic impacts of monetizing carbon on local people.

APPROACH

This study will conduct a multi-level analysis of a single REDD pilot project in Indonesia using both qualitative and quantitative methods. Data will be gathered to understand better the perspectives of forest-dependent communities, government agencies, nonprofit organizations, private-sector businesses and international institutions that are involved in or impacted by the selected REDD project.

EXPECTED RESULTS

The results of this research will help to understand how local, forest-dependent communities are impacted by REDD and if and how REDD and other "payments for environmental services" may be better designed to be more inclusive and locally beneficial while also being more effective at reducing deforestation.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The ultimate aim of this project is for the perspectives of people personally involved in and impacted by REDD to be added to global discussions on how market-based conservation and climate change mitigation strategies can be improved in the future.

Keywords: *Indonesia, forest-dependent communities, carbon sequestration, rainforest conservation, REDD*

Emerging Environmental Approaches & Challenges: Social Sciences
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EPA Project Officer: Jose Zambrana
Project Period: **9/1/2011 - 8/31/2014**
Project Amount: $126,000
Environmental Discipline: Environmental

Jennifer Liss Ohayon

E

Public Participation in the Environmental Remediation of Former Military Bases

Bio

Jennie Ohayon received a B.S. in Botany and Political Science from the University of Toronto. Prior to entering the Environmental Studies doctoral program at the University of California, Santa Cruz, she worked as a researcher in conservation biology laboratories. In 2010 to 2011, she was a fellow in a National Science Foundation-funded program, where she designed and implemented an inquiry-based environmental sciences curriculum in an underserved high school. She researches how community participation shapes decisions made about the environmental remediation of contaminated former military lands.

Synopsis

Military sites are ranked among the Nation's worst hazardous waste sites, posing threats to public and ecological health. Agencies, such as EPA, have incorporated public participation into environmental remediation decisions in the form of citizen advisory committees, workshops and funding for communities to hire independent technical experts. This research addresses how participatory structures influence knowledge production, attention to environmental justice and restoration objectives.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Many closed military installations are listed among the Nation's worst hazardous waste sites and incorporating meaningful public participation into decisions on environmental remediation is a key goal for several government agencies. This research project analyzes the relationship between different approaches to public participation programs and the production of scientific information and restoration outcomes in former military sites. As the implementation of participation programs has had mixed results, the project also examines factors that can contribute to gaps between policy promise and policy performance.

APPROACH

This research employs several case studies of former military sites in California on the federal National Priority List (NPL), which includes the Nation's most polluted sites. The project uses a range of qualitative methods, including close textual and contextual analysis of archival research, indepth interviews and participant observation, to assess different approaches to public engagement in environmental remediation decisions. Public participation strategies include citizen advisory committees, public hearings and workshops, and funding for communities to hire independent experts for scientific consultation. Interviewees encompass key scientific and technical professionals, community-based actors and representatives from government agencies overseeing or responsible for cleanup and restoration.

EXPECTED RESULTS

Findings from this research will identify barriers to public engagement in science policy on environmental remediation. This research will indicate how different participation programs influence the accessibility of scientific information for communities, with respect to both the availability of comprehensive and timely information and citizens' ability to interpret scientific and technical documents. Research findings will provide valuable insights for facilitating communication between communities and government agencies, addressing conflicts over the nature and type of scientific information and practice, and assessing how participation programs can be structured to increase opportunities for citizen knowledge and preferences to be incorporated in environmental decision-making.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

EPA estimates that there are approximately half a million contaminated sites nationwide and has broadly implemented public participation programs. From studying a diverse group of stakeholders and participatory approaches, this project will develop recommendations for increasing the capacity for community-level input into decision-making, including for cases where conflicts over remedial activities and environmental justice issues are prominent. The project focuses on an area where communities have traditionally been most excluded, on issues traditionally seen as primarily scientific-technical concerns, with the aim of furthering applied policy practices and enriching the research in participatory science policy.

Keywords: *environmental decision making, public participation, environmental justice, risk assessment, restoration, environmental remediation*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Geography

Kerri Jean Ormerod

E

Governing Risk, Reuse and Reclamation: Water Pollution Control and New Water Resources in the Southwestern United States

Bio

Kerri Ormerod received her undergraduate degree from the University of California, Berkeley, in Interdisciplinary Field Studies with emphases in City Planning, Public Health and Geography. She began her Ph.D. program at the University of Arizona School of Geography and Development in 2010. Her interests focus on the American West, urban growth demands and the politics of recycling the by-products of municipal wastewater treatment.

Synopsis

Highly treated municipal wastewater, known as reclaimed water, is an increasingly sought-after water resource. This research project examines three critical uncertainties that will govern the future use of reclaimed water: (1) public values and social pressure; (2) the political, legal and institutional contexts; and (3) the role of science and technology in defining ideas, facts, themes and solutions.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Highly treated municipal wastewater, known as reclaimed water, is an increasingly sought after water resource. This research project examines three critical uncertainties that will govern the future use of reclaimed water: (1) public values and social pressure; (2) the political, legal and institutional contexts; and (3) the role of science and technology in defining ideas, facts, themes and solutions.

APPROACH

Law—or governance—is the primary arena where social contestations regarding risk are mediated. This research project examines the formal, institutional and organized forms of risk management regarding water pollution control by paying particular attention to the legal dimensions of reclaimed water planning (including policy, laws, court decisions, regulations and citizen-led ballot initiatives), and the material and physical consequences of their logic (such as investment in wastewater treatments facilities, separate reclaimed water systems, and effluent-dependent ecosystems). This dissertation research also will address differences between the conventional logic of experts and the general public, as well as the role of law in balancing risks, advancing conservation goals, promoting equity and maintaining public trust.

EXPECTED RESULTS

By characterizing public attitudes toward reclaimed water, expected results of this research will help water planners and municipal utilities carefully address public concerns before setting reclaimed water policy and will allow for temporal, operational and strategic incorporation of behavioral considerations in the planning and implementation process.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Given the context of future water scarcity effectively integrating reclaimed water supplies will be crucial to sustaining both human and environmental health. Recognition of the social and legal assumptions and vulnerabilities identified in this research will be imperative for preventing conflicts over reclaimed water resources. In addition, this research will provide critical information about public perceptions of reclaimed water supplies that will increase understanding of public values and behaviors. The legal and institutional analyses included as part of this study also will highlight problems of definition that may become problems of the market, trade and regulation. Importantly, this research also acknowledges the environmental tradeoffs of greater reclaimed water utilization, especially for riparian habitats in the arid Southwest.

Keywords: *reclaimed water, risk perception, water quality, water supply, water pollution control*

Emerging Environmental Approaches & Challenges: Social Sciences
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Project Amount: $126,000
Environmental Discipline: Geography

Marta M. Ribera

E

Interdisciplinary Spatial Modeling to Foster Decision-Making in Marine Ecosystems

Bio

Marta Ribera was born in Gainesville, Florida, grew up in Barcelona, Spain, and earned her B.A. in Biology from the Universidad Autonoma de Barcelona. She worked for 5 years as a GIS analyst in the NOAA Fisheries laboratory in Panama City, Florida. In 2008, she moved to Boston, Massachusetts, to pursue a Ph.D. at the Boston University Department of Geography. Her research focuses on applying spatial modeling tools to inform fisheries managers of the optimal distribution of ocean uses in the Gulf of Maine.

Synopsis

The Gulf of Maine is a biologically diverse area and a significant driver of economic activity in New England. Managers are increasingly turning to ecosystem-based approaches to maximize the sustainability of fishing activities, which requires identifying areas vulnerable to overfishing. This project proposes to locate areas with both a high concentration of human activities and high ecological productivity, and then create a dynamic spatial model to determine the optimal use for each area.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Ocean ecosystems are complex, dynamic and spatially heterogeneous systems, and policies managing its resources should reflect these characteristics. The objective of this project is to create a spatially explicit model to help managers determine the optimal location for various fishing activities and conservation areas in the Gulf of Maine, with the end goal of ensuring a healthy and resilient ecosystem while still providing socio-economic benefits for its users.

APPROACH

This project will have two clearly defined stages. The first stage will use advanced spatial analysis techniques, such as Neural Networks, to determine the distribution of socio-ecological hotspots (areas characterized by an overlap of high biological productivity and human activities and where conflicts between conservation and commercial activities are most likely) across the Gulf of Maine. Secondly, once the locations of socio-ecological hotspots have been identified, a model will locate the optimal spatial distribution of different fishing activities and conservation areas. At the end of the project, this information will be integrated with a pre-existing Decision Support Tool named Marine Integrated Decision Analysis System (MIDAS) to ensure the modeling results can be visualized and used by fisheries managers.

EXPECTED RESULTS

In recent years, fisheries managers in the Gulf of Maine have started to move from single-species to ecosystem-based management (EBM). Due to the spatially heterogeneous nature of many marine resources, one of the tools that can be used for EBM is Marine Spatial Planning (MSP), which provides a systematic, integrative and participatory process for managing the target ecosystem. Spatial analyses of available data from the Gulf of Maine will identify areas with both exceptionally high productivity and high intensity of human activities. The proposed spatial model then will recommend the optimal distribution of fishing and conservation activities, which can potentially ease the MSP process and help resolve current conflicts.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The results of this research should enhance managers' understanding of, and therefore ability to manage sustainably, the complex and dynamic ecosystem of the Gulf of Maine. As a result, the ecological integrity of the system, as well as the many ecosystem services it provides, should be preserved for future generations. Moreover, with further refinement, this process could be potentially applied to other systems.

Keywords: *Gulf of Maine, ecosystem-based management, marine spatial planning, spatial modeling, hotspot mapping, decision-making*

Global Change

When one tugs at a single thing in nature,
he finds it attached to the rest of the world.

– John Muir

Global Change

Global Change
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Project Amount: $126,000
Environmental Discipline: Zoology

Gwendolynn Wolfheim Bury

G

An Integrated Approach to Gauge the Effects of Global Climate Change on Headwater Stream Ecosystems

Bio

Gwendolynn Bury received her undergraduate degree in Biology from Southern Oregon University in 2002, and Master's degree in Biology from Western Washington University in 2006. She is currently in the second year of a Ph.D. program in the Zoology Department at Oregon State University. Her research focuses on using sensitive stream amphibians as an indicator of ecological dysfunction in headwater streams of the Pacific Northwest. Currently, she is investigating the physiological responses of a native salamander to global warming.

Synopsis

Global climate change will impact many natural systems, including headwater streams. Headwaters provide important nutrients to the surrounding forest and to downstream, fish-bearing waters. This study focuses on a salamander that is very sensitive to disturbance, and is used as an indicator of the health of the stream. This research is looking for the specific causes of impact: temperatures at which the salamanders cannot live. This project integrates physical impacts with modeling to understand future effects on streams.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This work will study the effects of global climate change on headwater streams, using *Rhyacotriton variegatus* as an indicator of ecosystem dysfunction. Specifically, it will use a combination of physiological ecology, survey and modeling methods to look for the limiting factors in the health and survival of *R. variegatus*. Aim 1: Are *R. variegatus* disappearing from warming streams at the edge of their thermally defined range? Aim 2: What are the thermal tolerances of *R. variegatus* eggs? Aim 3: Are stress hormone levels of *R. variegatus* elevated in thermally degraded streams? Aim 4: How will global climate change affect the distribution of *R. variegatus*?

APPROACH

Aim 1: To address this aim, two methods will be used First, streams will be surveyed where *R. variegatus* were found historically, that are on the southern end of their thermally defined range. Second, electronic temperature loggers will be placed in a gradient of streams—streams on the edge of the range of *R. variegatus*, streams in the center of the range and streams just outside the range, to look for a temperature cut-off for *R. variegatus* presence. Aim 2: Female *R. variegatus* will be induced to lay eggs. Eggs will be kept in the laboratory at a range of environmentally relevant temperatures. Aim 3: In streams at the edge of *R. variegatus'* range, blood samples will be taken. Adult *R. variegatus* also will be held in the laboratory at a range of environmentally relevant temperatures and then blood samples will be taken. Samples will be analyzed for the levels of corticosteroid. Aim 4: Computer modeling and a GIS will be used to integrate the physiological limits found during the other Aims into future predictions of habitat loss for *R. variegatus*.

EXPECTED RESULTS

This study will provide a set of models that integrate climate and physiology of an indicator species. These models will allow for predictions of headwater stream dysfunction in the Pacific Northwest under a variety of possible climate scenarios. Results of this study also will provide causal data on a sensitive indicator, which is needed to accurately gauge disturbance, and is rare. Most indicator species are used in a correlation way—when they are not present, the ecosystem is not functioning. This study provides physiological causes for these correlations.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research will provide models to estimate the locations of streams that will be most impacted by global climate change. This will encourage targeted conservation and mitigation efforts in these and connected ecosystems. The causal physiological data on *R. variegatus* will encourage their use as an indicator of headwater stream health and provide specific reasons for declines if they are discovered.

Keywords: *amphibians, indicator species, headwater, streams, climate change, forests, Pacific Northwest, temperature tolerance, life stages*

Global Change
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Terrestrial Systems
Ecology - plants and soils

Andrew Brett Reinmann

G

Impact of Winter Climate Change on Soil, Canopy and Ecosystem Carbon Exchange in a Northern Deciduous Forest

Bio

Andrew Reinmann received a B.S. in Environmental Studies from Binghamton University in 2001. In 2006, he received an M.S. in Forestry from the University of Maine, where he studied the effects of tree harvesting on nutrient cycling in spruce-fir forests. For the following 2½ years, he worked as a biodiversity conservation biologist for a nonprofit organization in New York. In 2008, Andrew enrolled in the Ph.D. program in Biology at Boston University. He is currently studying the impacts of changes in winter climate on above- and belowground carbon fluxes in temperate deciduous forests.

Synopsis

Changes in climate may affect the ability of forests to mitigate climate change by altering the extent to which they can sequester carbon dioxide. Northern forests typically have a continuous winter snow pack that is important in regulating soil temperature and possibly carbon sequestration. The objectives of this research are to quantify the impacts of predicted changes in winter climate (i.e., reduced duration of snow pack) on the ability of northern deciduous forests to sequester carbon.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Northern forests typically have a continuous snowpack for much of the winter; however, winters with an inconsistent snowpack can have colder soils and a greater frequency and severity of soil frost. Climate models predict a reduction in snowpack depth and duration by the end of the 21st century in the northeastern United States, which may have important implications for ecosystem carbon fluxes. This research project will quantify the effects of a late-developing snow pack and increased soil frost on ecosystem carbon fluxes in a northern deciduous forest.

APPROACH

This snow pack manipulation experiment is being conducted in a mixed-deciduous forest at Harvard Forest located in central Massachusetts. During two treatment years, snow will be manually removed from three of six 13m x 13m plots for the first 5 weeks of winter to simulate late snow pack development and induce soil frost. Growing season canopy carbon exchange and sap flow will be measured in red oak (*Quercus rubra*) and red maple (*Acer rubrum*) trees in each plot. Heterotrophic, rhizospheric and total soil respiration and tree stem carbon dioxide efflux will be quantified in each plot throughout the year. By simultaneously measuring above- and belowground carbon dioxide fluxes, this study will be able to quantify the effects of a late-developing winter snow pack and increased soil frost on ecosystem carbon exchange. Phenology of leaf-out and root biomass production also will be measured to determine the importance of soil frost in the timing of these processes and to quantify their relationships with ecosystem carbon fluxes.

EXPECTED RESULTS

It is expected that snow removal will increase depth and duration of soil frost in winter and spring. This may result in reduced heterotrophic and rhizospheric soil respiration and canopy carbon dioxide uptake with a net effect of reducing ecosystem carbon exchange and the ability of mixed-deciduous forests to sequester carbon. It is possible that the expected decline in canopy carbon dioxide uptake will be smaller than the expected decline in heterotrophic soil respiration, which could result in either no change or an increase in forest carbon sequestration.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Because forest ecosystems provide an important sink for anthropogenic carbon dioxide emissions, it is important to understand how changes in climate may affect the strength of this sink. By filling in the gaps in the understanding of the response of ecosystem carbon fluxes to changes in snow pack duration, the results from this study will improve the ability to predict how carbon sequestration will respond to future changes in winter climate. This will facilitate the development of meaningful carbon dioxide emissions goals and policies that are more effective at mitigating anthropogenic climate change.

Keywords: *climate change, soil frost, carbon dioxide, soil respiration, canopy carbon exchange, forest ecosystems*

Global Change
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Atmospheric Chemistry

Gregory W. Santoni

G

Constraints on California and Arctic Methane Emissions Using a Regional Lagrangian Model and Aircraft-Based Measurements During the CalNex and HIPPO Campaigns

Bio

Gregory Santoni received his undergraduate degree in Chemistry and Physics from Harvard University in 2004. Before starting his graduate work, he taught Chemistry, Physics and AP Physics in Atlanta Public Schools through Teach for America. He is currently a Ph.D. candidate in the Department of Earth and Planetary Sciences at Harvard where his research focuses on measurements and modeling of long-lived greenhouse gases (GHGs). To that effect, he has worked on the development of instrumentation to measure GHGs such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), and combined aircraft-based measurements of these compounds with transport models to relate source locations to observed concentrations, thereby improving estimates of regional GHG emission rates.

Synopsis

Accurate emission inventories of methane are essential in regulating greenhouse gas emissions through California's Global Warming Solutions Act (AB32, 2006). Combined with an air-parcel-following model driven by high-resolution meteorological products, measurements taken aboard the NOAA WP-3 aircraft during CalNex 2010: The Nexus of Climate and Air Quality campaign will provide reliable constraints on methane emission rates both by sector (e.g., agriculture) and spatially over California.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The California Global Warming Solutions Act (AB32, 2006) requires the state to cap its greenhouse gas emissions at 1990 levels by 2020, roughly 15 percent below current levels. Uncertainties in emission inventories, however, present a significant hurdle for the California Air Resources Board (CARB) in both setting and tracking progress toward greenhouse gas reduction goals. Current emissions inventories for methane (CH_4), for instance, have never been validated at the regional scale and few data sources exist to characterize the effects of intensive agriculture in the Central Valley. Until CalNex—the Research at the Nexus of Climate Change and Air Quality campaign—no regional-scale observations were available to assess emissions inventories quantitatively. This study will address these limitations. Additionally, measurements taken during HIPPO (HIAPER Pole-to-Pole Observations) provide detailed distributions of CH_4 over the arctic, useful in constraining the controls on CH_4 fluxes in that region at seasonal timescales.

APPROACH

This study proposes generating reliable CH_4 emissions over California, disaggregated spatially and by sector (agriculture, other land use, industry, transportation, etc.), by using the extensive set of airborne CH_4 measurements acquired with the NOAA WP-3 aircraft during the CalNex campaign in conjunction with a regional-scale lagrangian particle dispersion model (LPDM). The Stochastic Time-Inverted Lagrangian Transport (STILT) model is an LPDM that can be used to estimate trace gas concentrations that correspond with individual measurements from an aircraft campaign or tower. STILT is particularly well-suited for estimating emissions because measured trace gas signals can be directly correlated back to specific upwind source locations. This study will use STILT along with high-resolution assimilated meteorological fields from the Weather Research and Forecasting (WRF) model and source *a priori* information to produce a "footprint"—a transfer function giving spatially and temporally resolved increments of CH_4 mixing ratio in response to emission fluxes along the space/time trajectories. This will allow for the optimization of the *a priori* information to generate reliable CH_4 emission inventories for California.

EXPECTED RESULTS

This study will provide a robust constraint on baseline California CH_4 emissions, allowing for further regulation, accountability of emissions and accurate tracking of progress towards achieving the goals put forth in AB32. This work also will improve understanding of the seasonality of arctic CH_4 emissions and examine the effects global climate change will have on future emission rates.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

CalNex provides an opportunity to produce reliable CH_4 emissions constraints that will inform future state climate policy decisions. NOAA and CARB cite the improvement of emissions inventories as one of the key research objectives underlying the CalNex mission, and the study presented here will help achieve this goal. Given that methane has a relatively long residence time in the atmosphere, regional emissions have global consequences to the climate system and therefore understanding the controls on CH_4 production and loss are essential in predicting future climate change.

Keywords: *climate change, atmospheric chemistry, methane, Largrangian modeling, emission inventory, Arctic, California, Global Warming Solutions Act, AB32*

Global Change
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Project Amount: $126,000
Environmental Discipline: Hydrology

Nicholas L. Silverman

G

Water Resource Management Strategies for Mountainous Forest Catchments Under Climate Change Scenarios: An Ecohydrologic Approach

Bio

Nicholas Silverman received his undergraduate degree in Physics and Engineering from Washington and Lee University in 2001 and a Master's degree in Mechanical Engineering from The University of Washington in 2004. After graduate school, he worked in Seattle, Washington, as a River Restoration Engineer, and in 2007 he received a Professional Engineering license in Water Resources Engineering. Currently, he is working towards his Ph.D. in the Watershed Hydrology laboratory at the University of Montana studying regional climate change effects on water resources.

Synopsis

Climate change impacts on water resources are still poorly understood, and while global climate models have predicted a warming trend over the next century, regional climate change impacts may vary considerably. This project explores the relationships between plants, water, topography and weather to better understand the effects of climate change at the watershed scale. An ecohydrologic model will be developed to analyze mitigation opportunities through forest management practices.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Climate change impacts to water resources still are poorly understood, and although global climate models have predicted an overall warming trend over the next century, regional climate change impacts may vary considerably. This project will explore the dynamic coupling between plants and water within mountainous forest catchments to better understand how changes in climate will affect watershed hydrology differently based on the topographic and vegetation characteristics of a basin. The results will help identify potential climate change mitigation opportunities through the optimization of forest management practices.

APPROACH

Global climate change predictions will be dynamically downscaled to the Western Montana region using the Weather and Research Forecasting (WRF) model produced by the National Center for Atmospheric Research (NCAR). These results will be compared to a similar study previously completed in California to identify regional differences in precipitation patterns and snow accumulation. Then the climate data will be used to run a newly developed ecohydrologic model to explore how topography and vegetation will affect stream discharge and soil moisture patterns within a watershed. Finally, various forest management strategies will be tested within the model to investigate methods to maintain healthy watershed hydrology under future climate change scenarios.

EXPECTED RESULTS

Although changes in snow melt and accumulation due to rising temperatures have been consistently identified at gaging stations around the United States, similar signals have been less consistent in stream discharge measurements. It is hypothesized that this may be a result of both a bias in the location of the snow gaging stations (most are at lower elevations) as well as a dampening effect from specific topographic and vegetative characteristics unique to individual watersheds. By studying the effects of topography, vegetation and mesoscale climate on watersheds, this study can explore the non-linear response expected in the stream discharge. It is then anticipated that forest management strategies such as thinning the forest through prescribed burns, planting more trees, planting different specie mixes and altering spatial vegetative patterns can be established to minimize climate change effects on water resources within distinct watersheds.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This project will further environmental protection in two ways. First, it will provide high resolution climate predictions that are the first of its kind for Western Montana. These predictions can be used by policy makers, researchers, community members and nonprofit organizations in the area to help better prepare for future climate scenarios. Second, the project will produce recommendations on forest management strategies for optimizing future water resources as well as produce a tool that can be used to explore climate change effects in other regions of the United States and the globe.

Keywords: *climate change, ecohydrology, modeling, mesoscale climate, forest management, water resources, watershed hydrology, topography, vegetation, ecology, meteorology, atmospheric science, snow*

Global Change
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Ecology

Lori A. Sutter

G

Intra- and Interspecific Response of Tidal Wetland Plants to Increases in Salinity and Inundation as Predicted by Changes in Sea Level

Bio

Lori Sutter had a successful career in coastal resource management and protection developing non-regulatory approaches to wetlands conservation. Combining a passion for ecology and the emerging geo-spatial technology of the time, she also designed decision support tools for conservation and restoration efforts across the country. After a brief hiatus, Lori realized her interest in teaching and returned to school to pursue a doctorate in Marine Science, emphasizing tidal freshwater marsh ecology.

Synopsis

International authorities have high confidence that sea level has increased as a result of global climate change. As sea level rises, marshes are expected to experience increased salt intrusion, tidal inundation and sedimentation. Interestingly, it is the freshwater tidal marshes that may experience the greatest shifts in ecosystem structure and function as a result of sea level rise. This work will evaluate the responses of tidal freshwater marsh plant communities to salinity intrusion.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Authorities are confident that the sea level is rising as a result of global climate change. Those marshes currently upstream of the salt front but still under tidal influence, tidal freshwater marshes (TFM), may experience the greatest shifts in ecosystem structure and function as a result of sea level rise. The overall objective of this work is to identify community level responses of tidal freshwater marsh plant communities to sub-lethal levels of salinity.

APPROACH

This project is taking a multi-pronged approach to investigate macrophyte response to both top down and bottom-up controls. This study will use observational field data along a salinity gradient to determine the spatial and temporal dynamics of vegetation communities (biomass, nutrient accumulation and net photosynthesis) as well as the community's relationship to soil nutrients and porewater chemistry. Using mesocosms, this study will measure the vegetative stress response to sub-lethal levels of salinity and what role inter-specific competition plays in observed community changes. Finally, through a manipulative field experiment, this study will determine the role of invertebrate herbivores in plant community structure and resource allocation.

EXPECTED RESULTS

Plants are anticipated to assimilate nutrients proportionally to what is bio-available in their respective environment. Generally, plants grown under higher salinity are expected to have lower biomass, net photosynthesis and tissue nutrient ratios (C:N and C:P) relative to those grown in lower salinity. For those that do not demonstrate a decline in net photosynthesis, biomass is expected to diminish under higher salt conditions, suggesting that individual plants are stressed to the point that they cannot make productive use of the carbon they are fixing. Perennial plants are expected to fix more carbon than annuals and store a meaningful amount below ground. Inter-specific competition also is expected to decline in the presence of higher salt. With an increase in salinity, C:N is expected to be driven down, thereby increasing the palatability of the vegetation and potentially exacerbating herbivory stress.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Since 1987, formal efforts to reduce nutrient and sediment pollution in the Chesapeake Bay have been underway through the establishment of total maximum daily loads (TMDLs) of nitrogen, phosphorus (P) and sediment. With increasing salinity, P is released from TFM sediment and made biologically available in the open waters of the estuary. As the salt front moves upriver in the face of sea level rise resulting from global climate change, P will be released from TFM where it was previously retained. Preliminary results of this work indicate that a salt tolerant species retains less P than the native TFM species. If P is released with increased salinity and the vegetation utilizes less, the additional nutrient inputs into the estuary may lead to unexpected issues with excess P that are not being considered in the current Bay P "diet."

Keywords: *tidal freshwater marsh, TFM, sea level rise, marsh community ecology, Chesapeake Bay diet*

Global Change
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Ecology

John Patrick Whiteman

G

How Do Polar Bears Cope With Summer Conditions Altered by Climate Change?

Bio

John Whiteman received an honors degree in Biology from the University of St. Thomas (Minnesota) in 2003, where he worked on a plant physiology research team. He moved into wildlife ecology and worked for several research institutions and government agencies, before earning an M.S. in Zoology and Physiology at the University of Wyoming in 2008. For his Ph.D. in Ecology at Wyoming, his research focuses on how animals adjust their physiology in response to environmental change.

Synopsis

Climate change is reducing the extent of Arctic sea ice and lengthening the summer melt period. During summer, these changes are forcing some polar bears (*Ursus maritimus*) to either follow melting sea ice into areas of deep water, or move to shore; both locations may contain few seals for prey. This research investigates the abilities of polar bears to fast and reduce energetic needs, to understand how they may cope with food deprivation.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Approximately 40 percent of polar bears globally exist in areas where the sea ice retreats from shore during summer, and individuals may choose to move to shore or follow the ice north. Climate change is reducing the extent of Arctic sea ice and lengthening the summer melt period and as a result, bears that follow the ice north in summer are located over areas of deeper water, and bears that move to shore must remain there for longer time periods; both locations may contain few seals for prey. This research seeks to understand the physiological and behavioral capabilities of polar bears to withstand food deprivation on ice over deep water and on shore, and the results will inform models of future population trends.

APPROACH

Polar bears are captured in early summer and sampled and fitted with GPS collars. They are then recaptured in late summer on sea ice over deep water and on shore. Sampling is repeated and the collar is retrieved. Changes over the summer are quantified for body condition and nutritional state, use of stored energy, protein conservation and reductions in activity and metabolic rate. These changes reflect whether bears are forced to fast and how they cope with fasting, given their location on ice or on shore.

EXPECTED RESULTS

In this project, it is hypothesized that polar bears on shore during summer employ two strategies: they may fast and reduce activity and metabolic rate, allowing them to minimize loss of body condition; or, they may consume alternative food items available only on shore and maintain normal activity and metabolism. In addition, it is hypothesized that bears on sea ice attempt to continue hunting and maintain high activity rates because prior to recent ice declines, this was a successful summer strategy; however, due to low seal density in deep water they are forced to enter a fast and reduce their metabolic rate to save energy. The results of this project can be used to generate parameters for population models that will forecast probabilities of population increase or decrease in the future, given changes in sea ice conditions.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Testing the hypotheses in this project will yield an understanding of how polar bears respond to sea ice loss during summer months. Understanding the behavioral and physiological consequences of this decision under altered summer conditions caused by climate change will provide insights on the long-term persistence of polar bears and assist in making informed management decisions for this symbol of the Arctic.

Keywords: *Alaska, Arctic, climate change, polar bear, sea ice,* Ursus maritimus

Human Health

Public Health

Risk Assessment and Risk Management

Health is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity.

– World Health Organization, 1948

Human Health

Public Health

Risk Assessment and Risk Management

Public Health

Human Health: Public Health
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Project Amount: $126,000
Environmental Discipline: Toxicology

Laura Victoria Dishaw

Neurodevelopmental Toxicity and Metabolism of the Flame Retardant, Tris (1,3-dichloro-2-propyl) Phosphate

H

Bio

In 2007, Laura Dishaw received her undergraduate degree from Le Moyne College where she majored in Biology and Psychology. After working for a year as a technician in an orthopedic research laboratory at the State University of New York Upstate Medical University, she started her Ph.D. work in the Integrated Toxicology and Environmental Health program at Duke University. Her project focuses on the adverse effects of flame-retardant chemicals on the developing nervous system.

Synopsis

Organophosphate flame retardants (OPFRs) are applied to a variety of consumer products, including furniture and baby products. Over time, they leach out of treated materials, often accumulating in dust. Infants and young children are predicted to have the highest levels of OPFR exposure via ingestion or inhalation of contaminated dust. Due to their structural similarity to known neurotoxicants, this project will evaluate the potential adverse effects of OPFRs on the developing nervous system.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Since the 2004 phase out of polybrominated diphenyl ethers (PBDEs), organophosphate flame retardants (OPFRs), particularly tris(1,3-dichloro-2-propyl) phosphate (TDCPP), have been used increasingly to meet state and federal flammability standards. Like PBDEs, OPFRs are known to leach out of treated materials and TDCPP has been detected at levels equivalent to PBDEs in household dust. OPFRs are structurally similar to organophosphate pesticides, a class of known neurotoxicants, and children are predicted to have the highest exposure to flame retardants (FRs). The aim of this project is to assess whether exposure to TDCPP and other OPFRs may elicit adverse effects on the developing nervous system.

APPROACH

A combination of *in vitro* and *in vivo* approaches will be used. PC12 cells, a neuronotypic rat cell line that has been used extensively to evaluate the developmental neurotoxicity of organophosphate pesticides, were used to screen TDCPP and three similar OPFRs (tris 2,3-dibromo-2-propyl phosphate, TDBPP; tris 2-chloroethyl phosphate, TCEP; tris 1-chloro-2-propyl phosphate, TCPP) for effects on cellular replication, cell number, cell viability and phenotypic differentiation. A zebrafish model will be used to assess morphological, behavioral and histological changes following developmental and chronic dietary exposure to these same compounds. The effects of OPFRs will be compared to chlorpyrifos (CPF), a well-studied organophosphate pesticide and known developmental neurotoxicant. Because the rates and pathways of metabolism are often integral to toxicity of a chemical, S9 liver fractions and primary hepatocytes also will be used to learn more about TDCPP metabolism in humans.

EXPECTED RESULTS

In the PC12 cell studies, it was found that exposure to an equimolar concentration of TDCPP resulted in deficits equivalent to or greater than that of CPF on measures of cellular replication and cell number, without affecting cell viability. TDCPP also altered the pattern of phenotypic differentiation, resulting in elevated expression of both the cholinergic and dopaminergic phenotypes. Subsequent comparisons of equimolar concentrations of TDBPP, TCEP and TCPP found equivalent effects on cell number. Like TDCPP, TDBPP elicited an increase in expression of both the cholinergic and dopaminergic phenotypes while TCEP and TCPP exposure resulted in an increase in cholinergic expression without affecting the dopaminergic phenotype. These data suggest that the extent of halogenation rather than the type of halogen substituent is a critical determinant of the effects on phenotypic differentiation. It is expected that developmental exposure of zebrafish to high concentrations of OPFRs will result in increased rates of mortality and malformations while lower concentrations will induce histological and behavioral abnormalities that are indicative of more subtle, neurotoxic effects. Chronic dietary exposure to TDCPP is predicted to result in accumulation of the parent compound and metabolites in the tissues of zebrafish and induce histological changes in the brain. The S9 liver fraction and hepatocyte studies will be used to identify important metabolites and metabolic pathways of TDCPP in humans.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Due to the potential for neurotoxicity and models suggesting that infants and young children have the highest exposure to FR chemicals, there is an urgent need to assess the potential for TDCPP and other OPFRs to elicit adverse effects on the developing nervous system. Furthermore, identification of the pathways and products of TDCPP metabolism can be used to estimate the rate at which this compound is eliminated from the body and determine biomarkers of exposure in the human population. The results of this proposal can provide regulatory agencies with data needed to make accurate risk assessments and guide decisions regarding the continued use of TDCPP and similar FR chemicals.

Keywords: *flame retardant, organophosphate, developmental neurotoxicity*

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Project Amount: $126,000
Environmental Discipline: Epidemiology

Kim Ann Gaetz

Free to Breathe, Free to Teach: Indoor Air Quality in Schools and Respiratory Health of Teachers

Bio

Kim Gaetz received her Bachelor's degree in Biology from The University of North Carolina (UNC) at Asheville in 2001. From 2002 to 2004, she served in the Peace Corps in Turkmenistan. After working as a pharmacy technician and an environmental assistant, she began the MSP.H./ Ph.D. program in Epidemiology at UNC at Chapel Hill, focusing on social factors that affect exposure. In 2007, she interned at the National Cancer Institute. She currently conducts research on indoor air quality and respiratory health.

Synopsis

Asthma exacerbations and allergies due to poor indoor air quality (IAQ) can reduce the productivity, concentration and attendance of teachers and students. School buildings often exhibit IAQ problems due to high occupancy and scarce funds. Dampness increases exposure to asthma triggers such as mold, dust mites, roaches and rodents. This study measures the impact of humidity and other school IAQ factors on asthma and allergy symptoms among North Carolina teachers, and tests IAQ best practices.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Excessive dampness in schools may affect respiratory health by increasing exposure to sources of allergens such as mold, dust mites, roaches and rodents. The "Free to Breathe, Free to Teach" research project will investigate how classroom average relative humidity affects the incidence of asthma exacerbations and allergies among public school teachers in North Carolina. To provide relevant prevention strategies to minimize dampness, it also will be important to examine associations between humidity control and indoor air quality factors such as building age, previous water damage, type of ventilation system and maintenance practices.

APPROACH

Indoor air quality factors were evaluated during school inspections in which school and classroom specific characteristics were recorded, including water damage, adequacy of ventilation and maintenance issues. Fixed and time-varying characteristics will be modeled as predictors of humidity control. To measure incidence of asthma exacerbations and allergies, weekly surveys on respiratory health outcomes and classroom conditions were administered to school teachers for up to 12 weeks of follow-up. To quantify dampness in each classroom over time, relative humidity (RH) and temperature were regularly monitored during this time period, using data logging hygrometers. The analysis will compare incidence of respiratory symptoms in teachers working in classrooms with high (> 50%) and low.

EXPECTED RESULTS

Previous studies have demonstrated associations between excessive dampness in the indoor environment and respiratory illness. This study will estimate the levels of classroom relative humidity associated with increases in asthma exacerbations and allergy symptoms in school teachers. These findings also will be important in suggesting which school and classroom characteristics assist in humidity control. The strengths of this approach include primary collection of longitudinal health and environmental data, designed to address the proposed research questions. Results from this study may reduce use of ineffective methods of humidity control and may increase preventive maintenance strategies linked to positive health outcomes.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The results may support practical methods to reduce asthma triggers in schools through preventative maintenance and humidity control. By examining the impact of poor indoor air quality (IAQ) on the general health, concentration and attendance of school teachers, the research may increase attention among school officials to providing good IAQ as an essential ingredient to creating a healthy learning and working environment.

Keywords: *indoor air quality (IAQ), asthma, environmental epidemiology, humidity, respiratory health, school environment, teachers*

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Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Natasha Hodas

Refined Ambient $PM_{2.5}$ Exposure Surrogates That Account for Outdoor-to-Indoor Transport and Their Application in Epidemiology Studies

Bio

Natasha Hodas received her B.S. in Atmospheric Science from Cornell University in 2007. She is currently in the Ph.D. program in Atmospheric Science at Rutgers University where she conducts research in a multidisciplinary team of atmospheric scientists, epidemiologists and biostatisticians. Her research focuses on improving estimates of human exposure to fine particulate matter. She currently is working to develop a model that predicts indoor concentrations of outdoor-generated particles.

Synopsis

Because people spend most of their time indoors, exposure to particulate air pollution mainly occurs in the indoor environment. Exposure estimates that take into account the modification of the chemical and physical properties of particulate matter with indoor transport are important for understanding and mitigating health effects associated with particulate matter exposure. This research aims to improve models of indoor transport of particulate matter to reduce error in health studies.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Because people spend most of their time indoors, exposure to ambient fine particulate matter ($PM_{2.5}$) mostly occurs in the indoor environment. Exposure estimates that take into account the modification of the chemical and physical properties of $PM_{2.5}$ with indoor transport are important for understanding and mitigating health effects associated with $PM_{2.5}$ exposure. This research aims to improve models of outdoor-to-indoor transport of $PM_{2.5}$ to reduce exposure error in air pollution epidemiology studies.

APPROACH

The Aerosol Penetration and Persistence (APP) Model describes the indoor concentrations of the major chemical components of ambient $PM_{2.5}$ as functions of their outdoor concentrations, residential air exchange rates, particle losses indoors due to deposition, and in the case of nitrate, indoor losses resulting from evaporation. Particle composition is taken into account in the APP model through the use of chemical-species-specific deposition rates and by accounting for the semivolatile nature of particulate nitrate. Deposition rates are functions of particle size and can be predicted from chemically resolved $PM_{2.5}$ size distribution data. In this work, geographic-regionspecific deposition rates will be determined from chemically resolved size distribution data from geographically diverse locations across the United States. The treatment of particulate organic carbon (OC) in the APP model also will be addressed in this research. Currently, particulate organic carbon (OC) is treated as nonvolatile. However, there is evidence that phase changes of organics following indoor transport have a large impact on the fraction of ambient OC that penetrates and persists indoors. A substantial database exists characterizing the volatility distribution of ambient organic particulate matter. This, in combination with gas-particle partitioning theory, will be used to simulate the gas-particle partitioning behavior of particulate OC in indoor air.

EXPECTED RESULTS

The research tool developed in this project can be used to identify geographic locations, seasons and temporal and spatial scales for which outdoor-to-indoor transport of ambient $PM_{2.5}$ is (or is not) a substantial source of exposure error in air pollution epidemiology. It also will provide a method to predict the indoor concentrations and characteristics of ambient $PM_{2.5}$ in indoor air from readily available data. The development of modeling tools to accomplish this will enable such refined exposure surrogates to be used in large epidemiological studies.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research advances existing models of $PM_{2.5}$ exposure, develops and evaluates a new method for estimating organic $PM_{2.5}$ exposure, and seeks to address disparities in exposure error for vulnerable populations. Because the fraction of outdoor-generated $PM_{2.5}$ that penetrates and persists indoors differs for homes above and below the poverty line, as well as with source proximity, this work especially is important for reducing exposure error for populations in urban areas and with low socio-economic status. The refined exposure surrogates developed in this work have the potential to improve understanding of the health effects associated with $PM_{2.5}$ exposure and will aid in the development of successful exposure mitigation strategies.

Keywords: *indoor air quality, particulate matter, exposure*

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Project Period: 09/01/2011- 08/31/2014
Project Amount: $126,000
Environmental Discipline: Geography

David Michael Hondula

Environmental Determinants of Heat-Related Risk

H

Bio

David Hondula is a Ph.D. student in Environmental Sciences at the University of Virginia currently examining the impact of extreme heat on human mortality in the United States. He also completed Master's and undergraduate degrees at the University of Virginia, where his research focused on synoptic-scale climate change, environmental influences on respiratory health and coastal storm impacts. David is a member of the International Society of Biometeorology and Association of American Geographers, and was a 2008 National Science Foundation Graduate Research Fellowship recipient.

Synopsis

Extreme heat is the leading cause of weather-related death and illness in the United States. Current warning systems succeed in forecasting hot periods but do not yet identify elevated risk zones at the sub-city scale. Mitigation and intervention strategies would greatly benefit from knowing specifically where heat-related deaths are most likely. This research examines the geographic variability of factors that contribute to local heat risk to improve heat event planning and response.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Summertime heat waves are the leading cause of weather-related deaths and illness in the United States. Many of these deaths and related illnesses are believed to be preventable via appropriate intervention measures such as providing cooling centers for the isolated and elderly. Current warning systems succeed in forecasting hot periods but do not yet identify elevated risk zones at the sub-city scale. This proposed research will examine the geographic variability of environmental factors that contribute to local heat risk.

APPROACH

This research aims to identify smaller scale zones within cities where heat-related risk is highest and build empirical models that relate risk to a suite of explanatory variables, including environmental conditions and the underlying spatial demographic and social characteristics of the metropolitan populace. Daily mortality records for the previous 25 years have been obtained for seven major metropolitan areas in the United States. The aggregated zip-code mortality response on and following extreme heat events will be compared to the background rate using re-sampling techniques. Bootstrapped regression models will be employed to relate high-resolution meteorological, air pollution, demographic and land cover data to the spatial variability in heat-related excess mortality. These models and related maps can be adapted by local agencies to improve heat management planning and response.

EXPECTED RESULTS

The research hypotheses center around the idea that significant variability in heat-related mortality exists within metropolitan areas. Models that explain a portion of this variability will likely include the environmental variables of air temperature, humidity and air quality, as well as demographic factors related to age, income and isolation. Furthermore, the local mortality response may be inconsistent from one heat event to another. It may be the case that heat events of greater duration particularly enhance death rates in the warmest places in cities. Local-scale differences in the seasonality of mortality also may be present, attributable to a lack of preparation/awareness among these sensitive groups, of whom a larger percentage suffer in the first or second major heat wave each year.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

By identifying populations and localities that are most sensitive to mortality risk during high heat events, this research is directly targeted at protecting human health. Further, it may contribute to safeguarding the environment by providing additional insight into the efficient application of air-conditioning resources in particular geographies and the benefit of clean air. A closer examination of how the environment and demographics interact to shape patterns of heat-related deaths can lead to a healthier living environment for many Americans.

Keywords: *heat wave, extreme heat, biometeorology, heat-health risk, human mortality, urban climate, air quality, remote sensing, demographic risk, warning systems*

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Project Amount: $126,000
Environmental Discipline: Social Sciences

Marianthi-Anna Kioumourtzoglou

Effect of Exposure Measurement Error in Air Pollution Studies: Two Case Studies

Bio

Marianthi-Anna Kioumourtzoglou received her undergraduate degree in Environmental Engineering from the Democritus University of Thrace, Greece, in 2005. The following year, she started her studies towards an M.S. in Public Health at the University of North Carolina at Chapel Hill. Upon graduation in 2007, she worked as an Air Resources Engineer with the California Air Resources Board in the Mobile Source Operations Division. In 2008, she began her studies toward a doctoral degree at the Harvard School of Public Health, in the Department of Environmental Health.

Synopsis

This work will focus on examining the effects of air pollution sources and pollutant properties on cardiovascular- and respiratory-related emergency hospital admissions. Furthermore, this work will examine whether statistical methods that integrate across pollution and health measures are able to reduce the impact of measurement error and de-attenuate risk estimates. Finally, this work will investigate the effect of exposure measurement error on chronic PM health effects.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Exposure measurement error has long been identified as an important issue in epidemiological studies of particulate matter. The proposed study will quantify measurement error in chronic PM health studies, introduced by measurements of $PM_{2.5}$ and its components at centrally located stationary ambient sites. Additionally, this study will examine whether statistical methods that integrate across pollution and health measures, such as structural equation and hierarchical models, are able to reduce the impact of measurement error and de-attenuate risk estimates.

APPROACH

To assess the impact of measurement error on the association between PM exposures and chronic health outcomes, personal $PM_{2.5}$ exposure and ambient concentration data from 10 validation datasets will be used. The estimated de-attenuation factors will then be used to develop regression calibration models to adjust for bias in studies of chronic PM health effects. Further, structural equation models will be used to examine the association between specific $PM_{2.5}$ sources and cardiovascular (CVD)- and respiratory-related emergency hospital admissions. To assess pollution sources, both source apportionment and supervised approaches will be considered. Finally, a hierarchical regression model will be employed to examine the association between pollutant properties and CVD- and respiratory-related emergency hospital admissions.

EXPECTED RESULTS

Although many studies have linked fine particles to adverse health outcomes, the specific particulate sources or chemical components responsible for the observed effects are not known. This study aims to provide insight in the PM constituents causing the health outcomes, while using methods that reduce the impact of measurement error and de-attenuate the risk estimates. Additionally, the estimated de-attenuation factors from the developed measurement error model can be used to adjust the estimates of previous cohort studies on the chronic effects of air pollution.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Results of this study will further the understanding of health effects from $PM_{2.5}$, improving the ability to interpret health risks from previous studies and to design future studies. Furthermore, this study will provide critical insights on the toxicity of $PM_{2.5}$ components and sources, helping to assess whether pollutants produced from different sources are more toxic than others. The findings will have significant implications for future epidemiologic studies, source-specific policy decisions and improved air quality monitoring.

Keywords: *air pollution, exposure measurement error, fine particles, source apportionment, structural equation models*

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Project Amount: $126,000
Environmental Discipline: Epidemiology

Kevin James Lane

Modeling Personal Exposures to Ultrafine Particles and Effects on Cardiovascular Health

H

Bio

Kevin Lane received his B.S. from Saint Michael's College in 2002. After graduation, he began working with the Harvard School of Public Health on the Trucking Industry Particle Study. He attended Tufts University for his M.A. in Urban and Environmental Policy and Planning. He is in the Ph.D. program in the Department of Environmental Health at the Boston University School of Public Health, and is researching the association between ultrafine particulate matter and cardiovascular health in populations residing in close proximity to highways in the greater Boston, Massachusetts area.

Synopsis

Highways are a major source of air pollution both near highways and regionally. Ultrafine particles (UFP) are created from fresh vehicle combustion. UFPs can be found at high levels close to highways and major roads, but there are no studies measuring near-highway UFP and health measures at the same time. This project seeks to develop methods to assign exposure to UFP for people living near highways and use that to analyze their association with markers of cardiovascular disease risk.

OBJECTIVE(S)/RESEARCH QUESTION(S)

There exists a dearth of research on particulate matter (PM) nanoparticles, or ultrafine particles (1-100 nm in aerodynamic diameter, UFP), and associated health outcomes. UFPs constitute a developing area of exposure and epidemiological research that requires novel modeling approaches to deal with bias stemming from the high spatial and temporal variability of this pollutant. This research proposal seeks to aid in filling this PM research gap through an examination of the association between UFP and cardiovascular health in populations residing in close proximity to an interstate highway in the greater Boston, Massachusetts area. Due to the high spatial-temporal variability of UFP, specific times of day, such as during rush hour traffic, create significantly elevated exposure windows. Actual exposures during these windows of time depend on where people are physically located and will require a more refined exposure assessment model to minimize misclassification so that the exposure-disease relationships can be observed.

APPROACH

This research study will design and evaluate an exposure assessment model that incorporates time-activity data as a way to deal with error from exposure misclassification before implementing the personal UFP exposure model in an epidemiological analysis. First, an analysis of the use of questionnaire derived time-activity data in designing a personal exposure assessment model will be conducted through a validation study using GPS units. The questionnaire data will be used to develop an exposure assessment model that includes time-activity data, and compare this with a model that does not adjust for time-activity to examine the errors and direction of bias in a health outcomes study. After the model has been developed and tested, it will be used in the health outcomes study to examine the association between exposure to UFP and cardiovascular health, measured as biomarkers of systemic inflammation with high sensitivity C-reactive protein (CRP), fibrinogen, plasma interleukin-6 (IL-6) and tumor necrosis factor-α receptor (TNFα), adjusting for other exposure and personal variables.

EXPECTED RESULTS

Current research into time-activity and movement patterns of populations indicate that people are highly mobile but relatively predictable in their daily routines and can result in misclassification of exposure in studies that focus on pollutants with high spatial and temporal variability using a residential location as the basis for the exposure model. The relative predictability of movement patterns would suggest that only limited data are needed on a person's daily activities to determine where they routinely may be found at a specific time of day. This indicates that time-activity data collected through questionnaires could be used to develop a more accurate exposure assessment model. Incorporation of time activity data into an exposure assessment model of UFP will allow for a comparison of associated cardiovascular health outcome risk between the unadjusted (residential only exposure) and time activity adjusted models. If the unadjusted model is biasing results towards the null, then it is expected that the time-activity adjusted model will yield a stronger association and smaller standard error for the ß-estimates. Exposure parameters such as occupational and ambient UFP intrusion into the indoor environment will be analyzed at this time and included in the final exposure assessment model that will be used in the full epidemiology analysis. Integration of time-activity data into the exposure assessment model should reduce exposure misclassification that can occur in a study of a pollutant like UFP with such high spatial and temporal variability, allowing for a more representative health effects association to be observed.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Vehicle emissions are the primary source by which people are exposed to UFP, and approximately 11 percent of U.S. households reside within 100 m of highways. There is a limited amount of epidemiological data available on the health effects of UFP, no national network to monitor UFPs and no standards to regulate emissions of UFP. This research will contribute to a new and growing body of analyses that can inform future policy discussions about whether to regulate UFP exposure and, if so, at what level. New policy solutions and monitoring strategies may need to be developed if UFP concentrations are found to be associated with adverse health effects in epidemiology studies.

Keywords: *particulate matter, ultrafine particles, nanoparticles, time activity, exposure assessment, cardiovascular health, air pollution*

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Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Maya Lakshmi Nadimpalli

H

Carriage of Livestock-Associated MRSA on North Carolina Swine Farms and Occurrence and Persistence in the Surrounding Environment

Bio

Maya Nadimpalli received a Bachelor's degree in Environment from McGill University in 2009. During her undergraduate career, she completed internships with the Massachusetts Environmental Health Association and a Massachusetts-based wastewater technology firm. She also conducted research on arsenic biomonitoring methods at Virginia Tech. Maya began her graduate work at the University of North Carolina at Chapel Hill in fall 2011. Her research is focused on the origins and dissemination of methicillin resistance in humans and the environment.

Synopsis

Methicillin-resistant *Staphylococcus aureus* is responsible for more fatalities in the United States than HIV/AIDS. Although hospital and community-acquired MRSA has existed for decades, a strain of MRSA associated with intensive swine production recently has been discovered. North Carolina is a leading producer of intensively-raised swine. This research seeks to assess the carriage of livestock-associated MRSA on North Carolina swine farms and to determine its occurrence and fate in the surrounding environment.

OBJECTIVE(S)/RESEARCH QUESTION(S)

It has been hypothesized that the emergence of livestock-associated MRSA in swine workers in the United States may be related to the subtherapeutic use of antibiotics in industrial animal production. To characterize the impact of this practice on MRSA carriage, this study will compare MRSA prevalence among industrial hog farm workers to MRSA prevalence among organic antibiotic-free swine farmers in North Carolina. Furthermore, this study intends to investigate the potential for livestock-associated MRSA to be transmitted through the environment. The study will genotype and confirm the presence of MRSA in surface waters proximate to concentrated animal feeding operations (CAFOs) in Duplin County, North Carolina, and will assess the environmental persistence of MRSA spread through swine waste.

APPROACH

MRSA prevalence will be assessed in 50 consenting antibiotic-free swine farm workers, 50 industrial hog farm workers, and up to two members of each worker's household via a short questionnaire and nasal swabs. Although the questionnaire will establish occupational, environmental and healthcare exposures to MRSA, swabbing will determine actual carriage of MRSA. Whole-genome sequence typing at TGen, Inc. will confirm whether colonies from MRSA-positive swabs belong to a livestock-associated strain. To investigate the presence of MRSA in surface waters near CAFOs, the study will use molecular methods to confirm more than 600 "presumptive MRSA" isolates already collected during a field campaign in Duplin County from 2010 through 2011. *S. aureus* isolates positive for the methicillin-resistance gene also will be submitted for whole genome sequence typing at TGen Inc., allowing for genetic comparisons among MRSA strains isolated from the environment and from humans. Lastly, the persistence of MRSA spread through swine waste will be assessed using bench-scale microcosm studies. Microcosms will replicate the natural conditions of Duplin County surface waters, and other waters or sediments of interest.

EXPECTED RESULTS

Studies in Europe have found a significantly lower prevalence of livestock-associated MRSA in organic, antibiotic-free swine farmers compared to industrial hog farmers. European studies have also documented the transmission of livestock-associated MRSA from farmers to members of their households. Although no comparable studies have been published yet in the United States, this study expects to find similar results. The study also expects to confirm the presence of MRSA in the environment surrounding swine farm manure spray fields, as the "presumptive MRSA" isolates collected from Duplin County surface waters exhibited the anticipated phenotype on MRSA-specific agar plates. Research on MRSA persistence in the environment, both *in situ* and in the laboratory, is limited. However, a Swedish study examining MRSA persistence in treated wastewater suggests that this pathogen may indeed be able to survive for a significant period of time, even under stress. This study expects to reach similar conclusions using bench-scale microcosm studies.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

MRSA is carried by up to 53 million people worldwide and is responsible for more fatalities in the United States than HIV/AIDS. Certain practices distinctive to CAFOs may be directly related to the increasing prevalence of livestock-associated MRSA, and may be responsible for its introduction into the environment. Research focused specifically on the links between MRSA carriage and industrial animal production will be critical in advancing the discussion as to whether some of these practices should be readdressed through legislation. In addition, research that is able to confirm the presence of livestock-associated MRSA in the waters surrounding CAFOs will provide important evidence of both surface water pollution and a potential human health impact.

Keywords: *MRSA, swine production, CAFO, antibiotic resistance, North Carolina*

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Project Amount: $126,000
Environmental Discipline: Health

Kory Christ Russel

H

Quantification and Modeling of Health Benefits and Reduced Caloric Expenditure as a Function of Improved Water Supply in Low-Income Countries

Bio

Kory Russel received both a B.S. in Environmental Biology (2003) and an M.S. in Environmental Science (2005) from Taylor University. Kory spent 3 years as a Peace Corps Volunteer in Mozambique teaching biology and HIV prevention. In autumn 2009, he enrolled in graduate studies at Stanford University, where he is currently working towards a Ph.D. in Civil and Environmental Engineering. Kory's research focuses on the caloric cost of fetching water in rural Africa, as well as on peri-urban sanitation solutions in low-income communities. His fieldwork is carried out in Mozambique and Haiti.

Synopsis

The effects of water supply improvements on the health of more than 1 billion women and girls worldwide that fetch water often are difficult to quantify. Improved community water points have the potential to generate health gains by reducing the physical burden of water fetching. This study aims to assess and quantify the health impacts of water improvement interventions in rural Mozambican communities, in terms of time and energy expenditures of household water supply.

OBJECTIVE(S)/RESEARCH QUESTION(S)

What is the impact of different levels of water supply service on the caloric cost of water fetching within rural communities in sub-Saharan Africa? What is the metabolic equivalent of task (MET) value of water fetching within a rural population in Mozambique? What share of total daily energy expenditure is accounted for by water fetching in rural Mozambique? What are the impacts on energy expenditure of water supply improvements in rural Mozambique? What factors determine the magnitude and distribution of those impacts?

APPROACH

The study comprises three parts: (1) The study will complete about 1,600 household surveys in 60 communities with the help of trained Mozambican enumerators, who will administer questionnaires using personal digital assistants (PDAs). Each household will be visited before and after a water supply intervention. Questions will be asked regarding water supply services, fetching practices and water quantities consumed. (2) Three communities will be selected for indepth investigation, including a sample of 10 adult females in each community. Study participants will be asked to perform water fetching and other daily activities while wearing a Zephyr Bioharness monitor. The monitor will measure the exertion of water fetching in a field setting, and will allow the estimation of fetching as a share of a total daily caloric budget. (3) In a laboratory based experiment, 30 female subjects will be asked to perform typical daily tasks while wearing an Oxycon mobile metabolic monitor, so as to obtain highly accurate metabolic data.

EXPECTED RESULTS

The study will yield the first known comparison between laboratory- and field-based estimates of the caloric costs of water fetching in rural Africa, as well as a rigorous estimate of the share of the daily caloric budget attributable to water supply. Findings also will include an assessment of the impacts of water supply improvements on caloric expenditures. Such insights ideally will shed light on which types of water supply interventions deliver cost-effective gains to rural households.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Water fetching represents a substantial health burden for more than 1 billion women worldwide. This research will help quantify that burden, and will inform future interventions that can reduce the time and energy costs, as well as the physical burden, of fetching water.

Keywords: *energy expenditure, water supply, water fetching, borewell, handpump, health indicators, developing countries, Africa*

Human Health: Public Health
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Epidemiology

Kelly Jo Sebastian

Epigenetic Markers of Exposure to Traffic and Pediatric Asthma

H

Bio

Kelly Sebastian received her undergraduate degree in Biology from Thomas More College in 2007. The following year, she was accepted into the Biomedical Science Flex program at the University of Cincinnati. After 1 year of rotations, she elected into the Ph.D. program in Epidemiology and joined the Molecular Epidemiology in Children's Environmental Health training program. Her research focuses on environmental exposures and respiratory/allergic outcomes. Currently, she is researching epigenetic biomarkers of traffic-related exposure and their link to pediatric asthma.

Synopsis

Studies have demonstrated a consistent link between exposure to traffic-related air pollution and childhood respiratory health. This study will potentially identify children at greater risk for the development of asthma by not only providing new measures for disease and exposure surveillance, prevention and management, but also new insights into critical periods of early-life exposure to traffic exhaust.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Although epigenetics has become an intriguing area of research concerning the development of childhood asthma, significant questions remain regarding epigenetic biomarkers of traffic-related air pollution and the critical timing of early-life exposure. This research project will investigate the relationship between diesel exhaust particle exposure and the methylation status of key asthma-related genes and surrogate markers of global methylation. In addition, this project will determine whether these epigenetic changes are associated with the development of allergic disease and asthma over time.

APPROACH

The first phase of this project is to identify and test the utility of salivary epigenetic markers as biomarkers of DEP exposure in the Cincinnati Childhood Allergy and Air Pollution Study (CCAAPS) cohort. The methylation status of the promoter region of IFN-γ and global methylation status of LINE1 and AluYb8, examined via pyrosequencing, will be explored among children exposed to varying levels of DEP. This study will be the first to utilize saliva as a DNA source to experimentally determine methylation profiles with respect to DEP exposure and pediatric asthma. If proven to be successful, this methodology would be critically important for advancing epidemiologic studies in large cohorts, especially those studying environmental exposures and childhood asthma. The second phase is to determine if allergic sensitization and/or asthma during childhood is associated with methylation of the IFN-γ promoter and/or LINE1/AluYb8. The CCAAPS cohort has been clinically examined annually at ages 1 through 4 and at age 7 for the development of allergic disease phenotypes and asthma.

EXPECTED RESULTS

Expression of IFN-γ has been shown to be regulated by DNA methylation. Thus, it is hypothesized that the DNA methylation status of the IFN-γ gene promoter region will be hypermethylated among children exposed to high levels of DEP compared to children exposed to low levels of DEP. Demethylation of LINE1 and Alu elements increases their activity as retrotransposable sequences, which may induce genomic alterations and ultimately deregulate gene transcription. Therefore, this study believes LINE1 and/or AluYb8 will be hypomethylated among children with high DEP levels compared to children with low DEP levels. Further, it is theorized that the methylation status will be significantly associated with allergic disease and asthma development.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

There have been minimal well-designed epidemiologic studies of ambient air pollution and the epigenome addressing the numerous allergic outcomes seen in pediatric asthma. Studies within well-established longitudinal cohorts like CCAAPS, which have tracked lifetime childhood exposure to traffic-related air pollution and the development of allergic health phenotypes and asthma, are needed. This study will potentially identify biomarkers of diesel exhaust exposure and susceptible populations by means of epigenotyping and will not only provide new measures for exposure and disease surveillance, prevention and management but also new insights into critical periods of airway development, asthma etiology and asthma severity.

Keywords: *diesel exhaust particles, pediatric asthma, epigenetics, DNA methylation, global methylation, gene-specific methylation*

Human Health: Public Health
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2013
Project Amount: $84,000
Environmental Discipline: Environmental Toxicology

Todd James Zurlinden

Development of Environmental Public Health Indicators for Organophosphorus Insecticide Mixture Exposure

Bio

Todd Zurlinden received his undergraduate degree in Chemical and Biological Engineering from Colorado State University in 2010. Currently, he is pursuing his M.S. degree in Chemical and Biological Engineering at Colorado State University. His research is concerned with developing environmental public health indicators as they relate to organophosphorus insecticides. Aside from research, Todd is active in education and learning, and in 2011, was awarded "Outstanding Graduate Teaching Assistant" by the Department of Chemical and Biological Engineering.

Synopsis

Organophosphorus chemicals (OPs) are the most widely used group of insecticides in the world. Because of their common use in household and agricultural settings, humans are frequently exposed to these chemicals. Chronic exposure to OPs is linked to serious health problems. The goal of this project is to understand the linkage between toxicants and human exposures, and develop quantitative metrics (EPHIs) that will be used to inform the creation of policies and programs to protect human health.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Nearly all people living in the United States are exposed to organophosphorus (OP) insecticides/pesticides, through household or agricultural applications or ingestion of residues on food. Building linkages between OP insecticide mixtures, human exposures and public health outcomes is critical in creating rational regulations and stewardship programs to protect human health. Such linkages can be formed through the development of suitable environmental public health indicators (EPHIs), important metrics that can be used for long-term tracking and surveillance of environmental public health, as well as assessing the actual impacts of environmental risk-management decisions. Unfortunately, existing EPHIs for OP insecticide exposure lack a rigorous health-based underpinning and do not consider cumulative exposure, and thus are limited in their applicability and usefulness. To address this critical deficiency, the principal objective of this project is to develop quantitative, health-effect-based EPHIs for OP insecticide mixture exposure.

APPROACH

The proposed approach begins with a surrogate measure of adverse health effects of OP insecticides, and uses quantitative and statistical models, coupled with data from environmental and biomonitoring studies to reconstruct the information necessary to compute appropriate EPHIs. The essential components of this methodology are: (1) biologically based models of the absorption, distribution, metabolism and excretion (ADME) of OP insecticides; (2) pharmacodynamic models linking OP insecticide metabolites and B-esterase inhibition; and (3) statistical models and supporting data for individual and population variability with respect to OP insecticide exposure.

EXPECTED RESULTS

The study anticipates that the methodology, models and tools developed in this project will help elucidate specific environmental public health indicators that can be measured and tracked over time to effectively link changes in OP insecticide levels to impacts on public health. These indicators will be derived from a synthesis of biologically based computational and statistical models, information about population variability as it relates to OP insecticide exposure and risk, data from environmental and biomonitoring studies, and knowledge about the mechanisms underlying the adverse health effects of OP insecticide exposure. Therefore, the study expects to produce EPHIs that are more accurate, relevant and useful than the statistically based measures currently in use, and consequently the overall benefit will be an improvement of EPA's ability to protect public health.

POTENTIAL TO FURTHER ENVIRONMENTAL/HUMAN HEALTH PROTECTION

Building linkages between OP insecticide mixtures, human exposures and public health outcomes is critical in creating rational regulations and stewardship programs to protect human health. Such linkages can be formed through the development of suitable environmental public health indicators (EPHIs), important metrics that can be used for long-term tracking and surveillance of environmental public health, as well as assessing the actual impacts of environmental risk-management decisions.

Keywords: *environmental public health indicators (EPHIs), bayesian statistics, PBPK/PD Modeling, organophosphorus pesticides*

Risk Assessment and Risk Management

Human Health: Risk Assessment and Risk Management
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Atmospheric Sciences

Ellen E. Kersten

Ensuring Community Co-Benefits of Climate Change Mitigation Policies in California

Bio

Ellen Kersten received her B.A. from the University of California (UC), Los Angeles, in 2006 in Geography and Political Science. She then moved to the San Francisco Bay Area where she worked as a Health and Housing Research Associate for the Greenlining Institute, and then as a Geospatial Technician for the Department of Environmental Science, Policy and Management (ESPM) at UC Berkeley, where she is currently a Ph.D. student. Her research focuses on environmental justice, health impacts of climate change and geospatial technology.

Synopsis

Many public agencies are implementing transformative land use and transportation policies to mitigate and adapt to the progression of climate change. Ellen Kersten's research uses geographic information systems (GIS) to create and evaluate measures of neighborhood vulnerability to climate change and mitigation policies. The results will illuminate how to improve measures of cumulative health impacts and ensure communities achieve environmental justice objectives.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This project examines the effects of smart growth and climate change mitigation policies and programs as they relate to environmental health and social equity priorities. It will evaluate and expand upon existing models and methods for vulnerability mapping and decision-making by creating a suite of metrics and evidence that account for cumulative environmental health impacts. It is guided by three complementary research questions: (1) How will land use and transportation policies and programs that intend to mitigate the effects of climate change affect communities differently? (2) What are the incentives and disincentives for communities to engage in local and regional land use and transportation planning? (3) How can climate change mitigation policies more effectively support environmental justice goals?

APPROACH

With a focus on California and a regional case-study of the nine county San Francisco Bay Area, this research will be completed in four stages. First, the study will use geospatial data and methods to characterize neighborhood vulnerabilities and resilience to climate change. Second, the study will assess the relationship between neighborhood characterizations and areas targeted by smart growth, environmental justice and climate change mitigation programs. The third step will entail an indepth evaluation of the historical and current physical and social environmental context in six selected neighborhoods to ground-truth the assessments and relationships from stages two and three. Lastly, the study will revise the metrics as needed and disseminate the resulting neighborhood needs assessment measures to local and regional planning agencies and community-based organizations.

EXPECTED RESULTS

This research will create scientifically valid, transparent metrics and methods for local and regional needs assessment to inform climate change mitigation policy priorities that address health disparities and environmental injustices. Given that there are limited resources to direct toward transportation and land use improvements, it is crucial for policy makers and community advocates to have the ability to ensure that resources are targeted to communities that could and should benefit most from focused interventions. The data, metrics, findings and policy recommendations from the four stages will be compiled and shared with state, regional and local agencies as well as community advocacy groups. They also will inform memos that will be submitted to agencies during periods of public comment on their planning and development processes.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The neighborhood measures created and shared during this project will enable researchers, planners, policy makers and community advocates to better identify and understand the double burden of historically inequitable distribution of resources and current vulnerability to climate change impacts. They will help identify the neighborhoods that have the most to gain, and lose, from climate change mitigation strategies. It also will provide a much needed perspective and approach to public agencies and community advocates that are working to incorporate public health risk assessment and environmental justice into climate change mitigation policies and projections.

Keywords: *environmental justice, GIS, cumulative impacts, climate change*

Human Health: Risk Assessment and Risk Management
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Health Risk Assessment

LaShanta J. Rice

H

Assessment of the Relationship Between Environmental Quality and Perceived and Actual Cancer Risk in Environmental Justice Communities in Metropolitan Charleston, South Carolina

Bio

LaShanta Rice received her undergraduate degree in Biology from Talladega College in 2004. Prior to graduating, she was a National Science Foundation Historically Black Colleges and Universities Undergraduate Program intern working with the West Anniston Environmental Justice Task Force. A year later, she completed a 1-year postbaccalaureate program in Cancer Biology at Meharry Medical College. The following year she entered a Master's in Public Health program at the University of South Florida. While pursuing her degree, she worked in diverse capacities at the Moffitt Cancer Center (MCC). For the past year, she has served as project coordinator for two federally funded research projects while simultaneously pursuing a Ph.D. in Health Promotion, Education and Behavior at the University of South Carolina (USC). Her research interests include environmental exposures, cancer and health disparities. She currently is involved in action-oriented community-based participatory research at USC in the Institute for Families in Society. She plans to explore the interplay between environmental conditions, social perceptions and cancer health disparities for her dissertation work.

Synopsis

This research will explore the relationship between environmental exposures, cancer risk and social perceptions or cancer risk among African Americans in environmental justice communities. Mixed methodologies will be used to gauge perceptions and inform community-based research to meet the needs of residents in these communities. Findings from this research will be valuable to communities of color that disproportionately host environmental hazards and are differentially burdened by cancer.

OBJECTIVE(S)/RESEARCH QUESTION(S)

African Americans have higher mortality rates and lower rates of survival for most cancers compared to all other racial and ethnic groups in the United States. Environmental justice researchers have demonstrated that African Americans live in communities that experience disproportionately higher health risks from the burden of and exposure to environmental hazards, including noxious land uses and high levels of EPA criteria air pollutants. Exposure to criteria air pollutants can lead to cancer or exacerbate other health conditions. To reduce burgeoning cancer risks among African Americans, this research will elucidate the role environmental exposures play in social perceptions and actual cancer risk across disproportionately exposed populations.

APPROACH

Using an existing community-based participatory research (CBPR) partnership between the Low Country Alliance for Model Communities (LAMC) and University of South Carolina (USC), quantitative and qualitative analyses, this project will explore the correlation between environmental quality and actual cancer risk and community perceptions of cancer risks. To accomplish this goal, an environmental community health survey will be distributed in census tracts in Metropolitan Charleston and used to inform focus groups in LAMC neighborhoods. Socio-demographic information will be collected from the 2000 and 2010 U.S. Census Bureau at the census tract level. Data from the South Carolina Central Cancer Registry (SCCCR) will be used to determine cancer risk scores. Geographic information systems will be used to depict the correlation between the spatial distribution of environmental hazards and cancer risk at the census tract level. Statistical analyses will determine if there is a significant difference in risk scores between percent black and percent white and assess levels of perceived risk by race/ethnicity, gender and group.

EXPECTED RESULTS

Gauging underlying causes of cancer health disparities in underserved communities is not an easy task; however, assessing the relationship between social underpinnings and environmental conditions could prove to be valuable for populations disproportionately burdened by cancer and other diseases. Assessing the non-biological factors that constitute a greater influence on cancer risk among African Americans may improve uptake of prevention services and improve gaps in health between and within populations. Populations in predominately African American or low-income census tracts will have lower perceived risk of cancer than their white or more affluent counterparts. There will be a positive correlation between the spatial distribution of environmental hazards and cancer risk scores at the census tract level. There will be an inverse correlation between environmental quality and cancer risk and cancer morbidity in predominately African American census tracts and low socioeconomic status (SES) tracts.

POTENTIAL TO FURTHER ENVIRONMENTAL/HUMAN HEALTH PROTECTION

There is limited knowledge about the level of impact that perceived cancer risk has on intent to be screened or that environmental quality has on cancer risk in low-income communities and communities of color. Information gained from this research may significantly increase understanding of the spatial and temporal variation of human exposure to actual environmental hazards and provide an understanding of the correlation between perceived risk and actual risk of cancer based on exposure burden. The proposed project will fill this gap and is one of a few studies to examine community exposure, perceived environmental quality, and perceived cancer risk. Ultimately, this research will elucidate the relationship between the spatial distribution of facilities that emit pollutants and risk of disease among African Americans residing in environmental justice communities.

Keywords: *environmental exposures, cancer, environmental justice, community-based participatory research, pollutants, risk perceptions*

Land Protection

I think the environment should be put in the category of our national security. Defense of our resources is just as important as defense abroad. Otherwise what is there to defend?

– Robert Redford,
Yosemite National Park dedication, 1985

Land Protection

Land Protection
Rice University (TX)
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EPA Grant Number: FP917297
EPA Project Officer: Jose Zambrana
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Science & Engineering

Oneida Ana Watson

L

Landfill Disposal Reduction and Electricity Generation From the Use of Municipal Solid Waste in Waste-to-Energy Technologies

Bio

Oneida Watson received her B.S.E. degree in Chemical Engineering and M.S.E in Environmental Engineering from the University of Michigan in Ann Arbor and has held several internships in the energy sector. She currently is pursuing her Ph.D. in Environmental Engineering at Rice University, where her research focuses on converting municipal solid waste into electricity via the use of waste-to-energy technologies (incineration, co-combustion with fossil fuels, gasification and pyrolysis).

Synopsis

Municipal solid waste is nonhazardous residential and commercial trash. It is primarily landfilled in the United States, raising environmental contamination concerns via leaching of pollutants into the soil and groundwater. This discarded waste may be used for electricity generation (EG) via waste-to-energy (WtE) technologies. This project evaluates several WtE technologies for EG efficiency, environmental impacts and economic viability to determine optimal regional placement for each.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Increases in electricity demand and the environmental contamination concerns associated with landfills have made the use of municipal solid waste (MSW) a target alternative fuel for electricity generation. This research will address which waste-to-energy (WtE) technologies are best suited to convert MSW to electricity by advancing the understanding of the thermodynamic properties of each WtE technology, and discerning how to optimize the deployment of these technologies by considering economic and environmental conditions, local MSW composition and other constraints.

APPROACH

This research will be conducted in two phases. The first stage will involve both static and dynamic simulations for each WtE technology using AspenTech™ software. This model will compare WtE technologies: gasification, pyrolysis, co-combustion and incineration for electricity generation (EG) efficiencies, pollutants and thermodynamic stability of pertinent reactions when varying MSW composition and local environmental conditions. The second stage will utilize the results from stage one in an energy system analysis (ESA), in addition to environmental and economic information gathered for local conditions. The ESA will incorporate a combined dynamic economic and environmental model that allows variations in policy scenarios.

EXPECTED RESULTS

It is hypothesized that these simulations will provide more accurate EG efficiencies by accounting for variations in the MSW composition and process operating conditions, as well as predict the benefits of reusing WtE technology by-products as secondary heating sources. This information can be used to further predict which WtE technologies should be deployed in a region based on EG efficiencies and local variations in environmental regulatory constraints and economic competition caused by energy market conditions.

Investigating these WtE technologies compared to incineration may show mitigation of air and water quality degradation when used with current environmental pollution controls by lowering pollutants such as NO_x and SO_x, while utilizing the MSW more efficiently than incineration.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Reducing landfill disposal will increase the amount of land available for other uses, and reduces the possibility of landfill leaching of contaminants into the soil and groundwater. Utilizing MSW as a fuel will partially displace traditional fossil fuels, such as coal and natural gas, reducing environmental impacts associated with fossil fuel extraction and combustion. The WtE technologies of pyrolysis, gasification and co-combustion have thermodynamic advantages over full oxidation (incineration) and can have lower air and water pollutant emissions.

Keywords: *waste-to-energy, municipal solid waste fuel, landfill disposal reduction, thermodynamic modeling, energy system analysis, AspenTech*

Nanotechnology

We are all united by our desire to improve the world we live in – and not only the world we live in, but the world our children and grandchildren will live in as well. That is what brings us together.

– EPA Administrator Lisa P. Jackson

Nanotechnology

Nanotechnology
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EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Public Health Sciences

Michele Noble Shepard

Risk Assessment and Life Cycle Analysis of Nanoscale Metal Oxides Used in Semiconductor Wafer Fabrication

Bio

Michele Shepard received a B.S. in Industrial Hygiene/Environmental Toxicology from Clarkson University and an M.S. in Environmental Studies from the University of Oregon. She has worked as an environmental health and safety consultant at Arthur D. Little, in the biotechnology industry, and as a vice president in the Woodard & Curran Environmental Management Consulting Group. She currently is in a Ph.D. program at the University at Albany College of Nanoscale Science and Engineering, with research focused on the environmental and occupational health aspects of nanotechnology.

Synopsis

Nanotechnology presents great promise for revolutionizing numerous fields and applications. The rapid growth and proliferation of engineered nanomaterials has led to an increasing need to better understand potential public health and environmental risks. This project assesses the material characteristics, potential sources of exposure and release and risk management practices for engineered nanomaterials that are used in chemical-mechanical planarization for semiconductor wafer fabrication.

OBJECTIVE(S)/RESEARCH QUESTION(S)

To maximize the benefits of nanotechnology and avoid unwanted consequences, additional data are needed to better understand potential environmental health risks and necessary control measures across the life cycle stages for specific nanotechnology applications. The goal of this project is to provide data on the material characteristics, potential pathways of exposure and release, and risk management practices for engineered nanomaterials associated with the chemical-mechanical planarization process in semiconductor wafer fabrication. Additional application of the combined risk assessment and life cycle analysis framework also will help further refine the assessment approach for nanomaterials.

APPROACH

To investigate the environmental and occupational health risks of engineered nanomaterials used in the chemical-mechanical planarization process for semiconductor wafer fabrication, this project will use risk assessment and life cycle analysis methods. Initial study phases include constructing a profile of the life cycle stages, reviewing relevant toxicological data, assessing workplace handling practices and control measures and determining potential pathways of exposure or release. Sampling and analysis will be conducted to identify and characterize any engineered nanomaterials in air and process waste streams. The approach also will include a review of current and best practice recommendations to prevent or minimize exposures and releases, including design considerations, engineering controls, workforce training, administrative procedures, personal protective equipment and waste management practices.

EXPECTED RESULTS

This project will result in a case study on the environmental health risks and recommendations for nanoscale metal oxides used in chemical-mechanical planarization for semiconductor wafer fabrication. The results will include an evaluation of material characteristics and exposure pathways across the life cycle stages, recommendations for risk management practices to prevent or minimize exposures and releases, and an assessment of the applicability of the current environmental regulatory framework for these specific materials. The results also will help clarify unknowns and uncertainties and prioritize further research needs related to the nanoscale metal oxides of interest, as well as to provide lessons learned and other refinements in applying combined risk assessment and life cycle analysis methods for engineered nanomaterials.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The project results will include recommendations to control worker exposures to these engineered nanomaterials and help prevent potential human health impacts, as well as to evaluate pathways for environmental release and potential downstream public health impact.

Keywords: *engineered nanomaterials, nanotechnology, nanoparticle exposure, environmental health, risk assessment, life cycle analysis, semiconductor wafer fabrication, chemical-mechanical planarization*

Nanotechnology
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EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Andrea J. Tiwari

Characterization of Incidental Carbonaceous Nanoparticles in Ambient Air and Combustion Exhaust

Bio

Andrea Tiwari is a Ph.D. student in the Civil and Environmental Engineering Department at Virginia Tech. After receiving her B.A. in Physics from Luther College in 2003, she worked at the U.S. Geological Survey and as a high school physics teacher. She then enrolled at Virginia Tech and received her M.S. in Environmental Science and Engineering in 2009. Her Ph.D. research focuses on the intersection of man-made nanoparticles and the Earth's atmosphere.

Synopsis

This research will examine aerosol samples from common combustion exhausts, such as diesel and coal, to investigate whether those exhausts contain specialized carbon nanoparticles called fullerenes. This work also will examine aerosol sampled in ambient urban and rural environments. The potential presence of carbon-based nanoparticles in the atmosphere may alter the way policy makers and researchers think about the environmental impacts of nanotechnology.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research will investigate whether C_{60} fullerenes are present in ambient air or in exhausts of common combustion sources. These results have implications for research and policy pertaining to carbonaceous nanoparticles as environmental pollutants.

APPROACH

For this research, aerosol samples will be collected on filters and on electron microscopy grids. Samples will originate from six sources: coal-fired power plant, diesel truck depot/industrial location, forest fire, ambient urban, ambient rural and laboratory control. All filters will be extracted to allow for quantification of any C_{60} content by liquid chromatography and infrared spectroscopy. Additionally, microscope grids will be analyzed using a transmission electron microscope to examine particle morphology. Comparing these results with previously published work alleging the presence of C_{60} based on particle morphology alone, this research will make definitive progress towards understanding the potential presence of C_{60} in the ambient atmosphere.

EXPECTED RESULTS

The most important result of this research is one of the most complete datasets to date on the presence of C_{60} in the aerosol phase in the natural environment. This study expects that C_{60} fullerenes will not be found at detectable levels in combustion exhaust, ambient carbonaceous aerosol or forest fire smoke, as the combustion conditions are far from optimal for C_{60} production. The results of this study should weigh rather heavily on the debate as to the state of nanocarbons in the natural environment. This will help the research community, as well as policy makers, understand the relative importance of nanocarbons when considering nanotechnology's potential impacts on the environment.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Knowing whether or not C_{60} is present in combustion exhausts and ambient air, and if so at what levels, will be very important when formulating environmental policy relating to nanoparticles as emerging pollutants. Because nanotechnology is a growing phenomenon in both the United States and global economies, effective nano-environmental policy is critical to protect the environment from the potentially negative impacts that manufactured nanoparticles may have on the environment.

Keywords: *C_{60}, fullerenes, nanoparticles, nanotechnology combustion, aerosol, incidental*

Pesticides and Toxic Substances

The EPA has a long history of understanding how toxic certain chemicals are. There's this realization now we can actually design chemicals and design manufacturing so they are less toxic and less polluting.

– Paul Anastas,
Director, Yale University Center for Green Chemistry and Green Engineering

Pesticides and Toxic Substances

Pesticides and Toxic Substances
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Toxicology

Erica Karin Anderson

P

Developing the Mosquitofish as a Robust Bioindicator Organism for Endocrine Disrupting Compounds by Elucidating the Molecular Mechanisms That Regulate Responses to Androgens

Bio

Erica Anderson completed her undergraduate studies at the University of Nebraska at Omaha in 2009. Erica was active in undergraduate research and also served as a university ambassador. After graduating with a B.S. in Environmental Studies with minors in Chemistry and Spanish, Erica enrolled in the Interdisciplinary Toxicology Ph.D. program at the University of Florida. Her research focuses on the impacts of endocrine-disrupting chemicals on aquatic species that inhabit paper mill-impacted habitats.

Synopsis

Endocrine disruptors interfere with hormone balance and can impact reproduction. Animals that live downstream of paper mills have abnormal characteristics that indicate exposure to endocrine disruptors. This project seeks to understand how female mosquitofish downstream of a Florida paper mill have male-specific physical characteristics. Field and laboratory work will be used to evaluate changes in gene expression and how this leads to the formation of abnormal characteristics in female mosquitofish.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Endocrine disrupting chemicals interfere with hormonal balance and can impact reproduction and development. Several species of aquatic animals that live downstream of paper mills have abnormal characteristics that indicate exposure to endocrine disruptors. In the State of Florida, one species of freshwater fish—the mosquitofish—has been observed with abnormal secondary sexual characteristics at three paper mill-impacted sites. This research project will delve into the mechanisms of how the female mosquitofish that live downstream of paper mills exhibit male-specific physical characteristics. Results will enable the mosquitofish to be further developed into an organism that can be sampled from polluted environments to determine the environmental impacts of paper mill effluents and other endocrine disruptors.

APPROACH

A combination of laboratory experiments and field work will be used to determine the role of gene expression in the development of the male-specific secondary sexual characteristic: the anal fin. In the laboratory, female mosquitofish will be exposed to endocrine disruptors (androgens) that are known to cause anal fin growth. Changes in the expression of genes known to regulate anal fin growth in other species will be monitored to determine the role of these pathways in mosquitofish anal fin growth. Further analysis of how these genes regulate one another will be determined in experiments with mosquitofish fry exposed to androgens and chemicals that can inhibit these genes. Hepatic gene expression analysis will be conducted on the androgen-exposed female mosquitofish using a microarray, a powerful technology that enables the quantification of thousands of genes at once. This microarray data will be compared to microarray data from the masculinized female mosquitofish that live downstream of the paper mill to determine if these fish are being exposed to a chemical that acts like an androgen. A biomarker of reproductive health also will be measured in field samples to determine if the abnormal female mosquitofish also may be impaired in their ability to reproduce.

EXPECTED RESULTS

Understanding the mechanisms that are responsible for abnormal anal fin growth in mosquitofish will allow for more accurate interpretation during field studies of endocrine disrupting chemicals using this species. This research also will provide information of the mechanisms by which paper mill effluents in the State of Florida are acting as endocrine disruptors and if this exposure is linked to potential reproductive effects. The long-term goal of this project is to develop the mosquitofish into a bioindicator: an organism that can be sampled from polluted environments to determine the environmental impacts and potential risks of chemical exposure for both wildlife and human populations.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Masculinized female mosquitofish still are found in Florida's freshwater systems that are impacted by paper mill effluents, and the risks of paper mill effluent exposure for other aquatic animals are greatly unknown. Determining the biological mechanisms that cause abnormalities in mosquitofish can help in understanding these effects and what risks may be conferred by other species in the area. This project can set the foundation for future studies using the mosquitofish as a bioindicator to evaluate the health status of paper-mill impacted sites and other ecosystems that are impacted by endocrine disruptors.

Keywords: *endocrine disruption, paper mill effluent, aquatic toxicology, bioindicator*

Pesticides and Toxic Substances
North Carolina State University (NC)
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EPA Grant Number: FP917322
EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Toxicology

Justin Matthew Conley

P

Conductivity and Selenium–Laboratory Approaches to Understanding the Impacts of Chemical Stressors Released From Mountaintop Mining/Valley Fill on Aquatic Insects

Bio

Justin Conley received his undergraduate degree in Environmental Science and Biology from Warren Wilson College in 2004. He went on to receive his M.S. in Environmental Science at the University of Tennessee at Chattanooga, where he conducted research on the presence of pharmaceutical residues in the Tennessee River. He began the Ph.D. program in Environmental Toxicology at North Carolina State University in 2008. His research focuses on the toxicity of chemicals released from mountaintop removal/valley fill coal mining to aquatic insects, specifically the effects of selenium and total dissolved solids on mayflies.

Synopsis

Degraded ecological conditions downstream of mountaintop removal/valley fill coal mining operations have been linked to water chemistry changes. Specifically, elevated selenium (Se) and total dissolved solids (TDS) are highly correlated with impaired aquatic life, including loss of aquatic insect abundance and diversity. This research program will seek to characterize the toxicity of Se and TDS to aquatic insects using a laboratory-based periphyton-mayfly test system.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Mountaintop removal-valley fill coal mining practices bury headwater streams and significantly change water chemistry in downstream reaches. It is unclear which contaminants are most responsible for observed ecological damage (dramatic reductions in aquatic insect abundance and diversity); however, elevated concentrations of selenium and total dissolved solids (as measured by specific conductance) are strongly correlated with ecological effects in the field. Little is known about how these contaminants affect aquatic insects, as laboratory data presently are limited. This research program will assess the potential toxicity of elevated selenium and specific conductance (individually and jointly) to aquatic insects by using a laboratory-based periphyton-mayfly test system.

APPROACH

To assess the toxicity of elevated selenium and total dissolved solids, a representative mayfly (*Centroptilum triangulifer*) will be used in controlled laboratory exposures conducted at environmentally relevant exposure levels and through ecologically relevant exposure pathways. *C. triangulifer* will be exposed in full life-cycle assays to a range of selenium contaminated periphyton diets and to waters with a range of conductivities that mimic the ionic composition of valley fill impacted streams. A combined experiment will determine if exposure to both dietary selenium and high total dissolved solids produces an increased toxic response, or if one of these stressors is the primary driver of toxic effects. This research further will seek to characterize the uptake kinetics of different inorganic selenium species into periphyton as well as identify the individual ions in high TDS waters that are most toxic to mayflies.

EXPECTED RESULTS

The expected outcome of this research program will be a much more environmentally relevant understanding of the toxic effects exerted by selenium and high total dissolved solids on aquatic insects, which currently are unknown. Characterization of selenium toxicity will be leveraged with experiments designed to describe the bioavailability of selenite versus selenate to primary producers, which dictate the bioaccumulation of selenium in food webs. Further, it is unknown whether any particular anion or cation in valley fill impacted streams is particularly toxic or whether the full assortment of ions present is necessary to produce effects. This research program will seek to clarify these uncertainties.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The focus of this research program is on aquatic macroinvertebrates, which are sentinels of water quality and aquatic ecosystem health. Recent research has shown a direct link between the health of these systems and cancer rates in residents of the Central Appalachians. This is a socio-economically depressed region and many consider mountaintop removal to be an environmental justice issue. By providing additional support to EPA administrators to set scientifically defensible water quality standards for specific conductance and Se, environmental improvements in water quality may potentially lead to improvements in human health in the area. Nationally, the EPA has for years been attempting to implement an updated Se standard. This research will fill significant data gaps in the science of understanding how Se moves through aquatic food webs towards upper trophic level organisms such as fish. Further, the issue of salinization of freshwater is a global issue with the encroachment of marine waters due to sea level rise, the extraction of natural gas from Marcellus shale brines, and evaporation of inland waters from climate change. Understanding the toxicity of specific ions to a representative sensitive aquatic insect will bolster the greater scientific understanding of how conductivity perturbs natural systems and aids in improving water quality globally.

Keywords: *mountaintop removal, valley fill, coal mining, selenium, total dissolved solids, conductivity, mayfly, insect, toxicity*

Pesticides and Toxic Substances
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 09/21/2011 - 09/20/2014
Project Amount: $126,000
Environmental Discipline: Civil/Environmental Engineering

Mackenzie R. Gavery

P

An Epigenomic and Transcriptomic Framework for Identifying Novel Modes of Action and Physiological Effects of Endocrine Disrupting Compounds in Shellfish

Bio

Mackenzie Gavery earned her B.S. in Biology from Seattle University where she focused in Marine Biology and spent summers studying Marine Ecology in Washington's San Juan Islands. After graduation, Mackenzie entered Seattle's biotech industry, applying molecular techniques to evaluate biologic drug candidates. In 2008, she entered the M.S. program in the University of Washington's School of Aquatic and Fishery Sciences. Her research aims to improve understanding of the physiological responses of marine invertebrates to natural and human-driven environmental change.

Synopsis

Endocrine disrupting compounds (EDCs) are environmental contaminants that threaten water quality and health of humans and wildlife worldwide. Although physiological effects of EDCs have been described, it is evident that understanding of the mechanisms and biological pathways affected are incomplete. This project investigates novel mechanisms of endocrine disruption by characterizing epigenetic changes and physiological responses to EDC exposure in a key aquatic bioindicator, the Pacific oyster.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Concern over human and wildlife health has brought increased attention to a group of emerging environmental contaminants referred to as endocrine disrupting compounds (EDCs). Although progress has been made in describing the effects of these compounds, there still are gaps in the understanding of alternative modes of action and physiological effects outside of the reproductive axis, particularly in invertebrates. This research aims to characterize alternative modes of action of EDCs by utilizing molecular tools to examine epigenetic and physiological changes in Pacific oysters (*Crassostrea gigas*) exposed to EDCs in the laboratory.

APPROACH

This research will consist of laboratory-controlled exposures of Pacific oysters to known EDCs (17a-ethinyl estradiol [EE2] and cadmium). High-resolution genome-wide DNA methylation profiling will be used to test the hypothesis that invertebrate DNA methylation patterns will be altered upon exposure to EDCs. An integration of traditional morphological as well as gene expression analysis will be used to assess physiological effects of EE2 and cadmium in this important bioindicator species.

EXPECTED RESULTS

The successful completion of this research will be able to provide: (1) a deeper and broader understanding of the modes of action of endocrine disrupting compounds; (2) the first integrative study using epigenetics, transcriptomics and phenotypic analyses to evaluate the effects of EDCs in an aquatic invertebrate; and (3) a proof of concept framework, which can be applied to advance the study of the biological effects of EDCs in other aquatic species.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research will increase understanding of both the modes of action and physiological effects of endocrine disrupting compounds to best evaluate risks and impacts to organismal health, population resilience and ecosystem structure. In addition, it is anticipated EDC exposure will produce unique epigenetic and gene expression "signatures" that are indicative of exposure and therefore can be utilized as early detection biomarkers.

Keywords: *endocrine disrupting compounds, epigenetics, transcriptomics, toxicology, aquatic invertebrates, oysters, mode of action, biomarker, gene expression, bioindicator, cadmium, 17a-ethinyl estradiol*

Pesticides and Toxic Substances
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Terrestrial Systems
Ecology - includes animals

Aaron Donald Gross

P

Targeting an Octopamine Receptor From the Southern Cattle Tick (*Rhipicephalus microplus*) for Targets of Biopesticides

Bio

Aaron Gross received his B.S. degrees in Biochemistry and Biomedical Science at St. Cloud State University, St. Cloud, MN, in 2007. He received his M.S. in Toxicology from Iowa State University of Science and Technology, Ames, IA, in 2010, and was a runner-up for the Midwestern Association of Graduate Schools 2011 Distinguished Thesis Award. His M.S. thesis investigated the activity of terpenoids against an American cockroach octopamine receptor. Aaron is continuing his education at Iowa State University to obtain a Ph.D. in Toxicology with minors in Entomology and Neuroscience. His research will focus on the use of natural and biorational products as agents for control of the southern cattle tick, a devastating pest that is rapidly re-emerging in the United States.

Synopsis

This research will address the growing concern of the re-introduction of the economically devastating southern cattle tick into the southern United States. This tick poses a significant threat to the cattle industry by transmitting diseases that can result in significant losses. This research will evaluate the potential of naturally occurring plant compounds for their toxicity to ticks by interacting with a specific neurological receptor (octopamine), which is not found to a significant degree.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The southern cattle tick, which transmits the causative agents leading to Texas Cattle Fever, can result in significant economic losses to the cattle industry. The southern cattle tick resurgence has recently intensified, resulting in the need to identify safe and biorational control measures to aid in the integrated approach to controlling this tick. This research project will identify and investigate an octopamine receptor from the southern cattle tick for the development of botanical terpenoids as acaricides.

APPROACH

Preliminary results have identified a putative octopamine receptor from the southern cattle tick, which has been validated to be a relevant acaricide target, and will serve as the basis for the first phase of the research performed. Functional response of the putative octopamine receptor will be accomplished by using a yeast histidine-auxotrophic assay to confirm that this receptor responds to the putative ligand, octopamine. The yeast assay will create a high-throughput platform to screen libraries of potential compounds that interact with this receptor. Octopamine and lead compounds identified from the yeast assay will undergo a more rigorous investigation into the pharmacology of the putative octopamine receptor. This will generate new data on receptor pharmacology, specifically activation of downstream cellular processes (second messengers), that cannot be attained with the yeast histidine-auxotrophic assay and will provide a higher level of scrutiny to receptor classification. The most important compounds identified with the cell expression assays will be tested against strains of ticks that are susceptible or resistant to synthetic acaricides.

EXPECTED RESULTS

Use of biorational botanical compounds against insects and acarines has increased in the past several years. It has been proposed that natural compounds may provide several mechanisms of action, including interacting with octopamine receptors. Although the results that are expected to be obtained by performing this research will not solve the continued threat of the southern cattle tick, it is expected to augment the multiple approaches that are needed in an arsenal to combat resurgence of this economically important pest. This research is expected to identify an octopamine receptor from the southern cattle tick and describe the activation of second messenger systems. It also is expected that this research will identify a variety of terpenoids that interact with this putative octopamine receptor to some degree. Identified octopaminergic candidate compounds will be tested against ticks to investigate adverse physiological response(s) and/or death. Compounds that display octopamine receptor activity and lethality can be used to generate quantitative structure-activity relationships (QSARs) that can be utilized to identify additional effective compounds based on unique physicochemical properties. Generation of new information about the pharmacology of the tick's octopaminergic system will be a significant advance in the understanding of acarine neurobiology. This research also may assist in controlling the spread of these ticks not only in the United States but also in Mexico, Central America and South America where this tick has significant impact.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Currently and previously used conventional insecticides can have significant adverse impacts on human health and the environment, including non-target wildlife. The movement towards biorational compounds may decrease the negative impacts on the environment and decrease public concern over the safety of currently used products.

Keywords: *octopamine, octopamine receptor, GPCR, southern cattle tick, Texas cattle fever, terpenoids, essential oils, biorational, biopesticides*

Pesticides and Toxic Substances
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Tyler Leon Hicks

P

Non-Target Impacts of Herbicides on Endangered Butterflies

Bio

Tyler Hicks graduated from Western State College of Colorado with a B.A. in Biology. He is currently a Ph.D. student at Washington State University-Vancouver, where he is studying the non-target impacts of herbicide use on at-risk Pacific Northwest prairie butterflies. In addition, he serves as a science adviser to Birds Korea, a group dedicated to conserving avian biodiversity in the Yellow Sea ecoregion of East Asia. Broadly, he is interested in the use of decision analysis, using science and an integral multi-perspective approach, to resolve complex wildlife management issues.

Synopsis

Invasive weeds are an increasing threat to native biodiversity. Due to their degree of selectivity, herbicides represent a valuable tool for land managers and conservation biologists to use in managing invasives and maintaining native flora and fauna. However, the impacts of herbicides on non-target species are not well understood. This project intends to identify ways to minimize harmful impacts of herbicide use on at-risk prairie butterfly species while maximizing control of invasive weeds.

OBJECTIVE(S)/RESEARCH QUESTION(S)

In cooperation with federal and state land managers, this project intends to identify ways to minimize harmful impacts of herbicide use on at-risk prairie butterfly species in the Pacific Northwest while maximizing control of invasive weeds.

APPROACH

Initially, this project will employ captive greenhouse studies with a non-native forb feeding and a native grass feeding butterfly species. Butterflies will be exposed to various combinations of surfactants and herbicides at different life stages. Impacts will be monitored by measuring survival rates, morphology, development time and fecundity. After identification of an herbicide/surfactant combination with a minimal impact, greenhouse studies will be scaled up to management landscape scales in the field in prairies occupied by the endangered Fender's Blue Butterfly (*Icaricia icarioides fenderi*). Finally, the study will monitor the response of the Fender's Blue to herbicide exposure and resulting changes in their habitat by measuring responses in survivorship, behavior, reproductive success and dispersal. By comparing multiple species in both controlled greenhouse and field conditions, decisions can be better informed on what, when and how to apply herbicides in the presence of at-risk butterfly species.

EXPECTED RESULTS

Management and recovery of threatened and endangered species is a priority for a number of federal, state and local land managers. In the Pacific Northwest and in other regions of the world, grassland butterflies are declining dramatically. Invasive weeds represent a major threat to remaining prairie obligate species. Herbicides are an important tool for land managers to use in managing invasive weeds. However, the potential non-target impact of herbicides on butterflies has not been explored thoroughly. Current herbicide usage may be causing harm to at-risk butterfly species. On the other hand, land managers unwilling to risk herbicide use may be missing out on a valuable management tool. This project intends to fill gaps in ecotoxicological knowledge by applying rigorous science to inform prairie management practices. This research project will expand the knowledge of herbicides impacts on prairie butterflies by using multiple species, including the at-risk Fender's Blue butterfly in both captive greenhouse settings and at practical landscape management scales in the field. With this data, it is hoped to develop recommendations for herbicide use in the presence of at-risk prairies butterfly species in the Pacific Northwest and in grassland systems across the temperate regions of the planet.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

By identifying herbicide use practices that minimize non-target impacts on native species and maximize control of invasive weeds, ecosystems can be maintained with greater native biodiversity and meet federal and state mandates for recovery of endangered and threatened species.

Keywords: *conservation, butterfly, herbicides, ecotoxicology, prairie management, non-target impacts*

Pesticides and Toxic Substances
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Project Period: 8/1/2011 - 7/31/2013
Project Amount: $84,000
Environmental Discipline: Atmospheric Sciences

Jeffrey Jackson Hillis

P

Are Male Bluegills (*Lepomis macrochirus*) Experiencing Altered Reproductive Output Due to Exposure to Chlorinated Hydrocarbons?

Bio

Jeffrey Hillis graduated *cum laude* from the University of Missouri-Columbia in 2007. During this time, he worked as a field technician for the University and as a scientific aide for the U.S. Geological Survey. After graduation, Jeffrey accepted a position with Analytical Biochemistry Laboratories as an assistant toxicologist. After 2 years of employment, Jeffrey went back into academia to pursue his M.S. in Aquatic Toxicology, with a research interest in endocrine disruption.

Synopsis

The chemical disruption of the endocrine system by man-made chemicals is a public health concern. Evidence indicates that endocrine disrupting chemicals (EDCs) in animals could disrupt reproduction processes. Chlorinated hydrocarbons (CHs) such as polychlorinated biphenyls and organochlorine pesticides act as EDCs and are present in aquatic systems. The objective of this study was to investigate whether increased incidence of gonad abnormalities is correlated with elevated CHs in bluegills.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The overall objective of this study is to quantify the concentration of chlorinated hydrocarbons (CHs) in male bluegill (BLG) in Illinois and relate these concentrations to the incidence of gonad abnormalities and the gonadosomatic index observed in field collected fish. This research will evaluate whether environmentally relevant levels of CHs affect the reproductive success of male BLG.

APPROACH

The objective of this study will be answered by collecting 50 bluegill (both male and female) from lakes with fish consumption advisories for polychlorinated biphenyls (PCBs). All fish will be dissected, and male gonads will be weighed and preserved for histology. Histology slides will be stained with hematoxylin and eosin. The slides will be evaluated at 400X magnification, and pictures of testicular oocytes or other abnormalities will be obtained. The carcass, minus gonads, will be homogenized with a high-speed blender and frozen for contaminant analysis. The whole body fish tissue sample will be analyzed for 28 PCB congeners and nine organochlorine pesticides. Two surrogates will be used to verify extraction efficiency. Male gonad abnormalities will be compared to chlorinated hydrocarbon concentrations to examine if there is a positive relationship. In addition, a reproductive trial in outdoor ponds will be conducted using male bluegill from the highest contaminant concentration group observed from the field collection. These male bluegill will be paired with females from a reference lake (less than background concentrations) to examine male reproductive success. These fish will be compared to a control group with both male and female bluegill collected from the same reference lake.

EXPECTED RESULTS

The results of the field collection will show that the gonadosomatic index from male BLG taken from the CH lakes will be statistically significantly lower than males in the reference lake (Fisher's exact test [$\alpha = 0.05$]). Concentrations of CHs in body residues of adults will be elevated in lakes with sediment concentrations >1.7 mg/kg (extreme effect concentration). The reproductive trial hypothesis is that male BLG from CH contaminated lakes will have significantly lower ($\alpha = 0.05$) reproductive output (amount of young produced) than that of males from the reference lake. Whether this condition is due to altered mating behavior or impaired reproduction will not be evaluated. Research into how CHs reduce reproductive output should be pursued further if this is observed. Application of this research may reveal that it is important for fisheries managers to assess the incidence of intersex and sex ratio of BLG in lakes that have a history of CH contamination. Maternal transfer of CHs depends on the contaminant concentrations of the female parent. Therefore, it is hypothesized that this will minimize the concentration of CHs observed in the juvenile BLG during the reproduction trial.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Male behavior and fertility is an important reproductive component in animal populations. Legacy contaminants such as polychlorinated biphenyls and organochlorine pesticides are long lived and their effects still are being understood. Using the BLG species as a surrogate, this research will evaluate how CH concentrations may affect the reproductive ability of male animals including humans. Insight into reduced fertility found in bluegill may provide information about how legacy contaminants are reducing male fertility by either affecting behavior or via physical impairment.

Keywords: *endocrine disruption, bioaccumulation, reproduction, polychlorinated biphenyls, organochlorine pesticides*

Pesticides and Toxic Substances
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Toxicology

Jessica I. Lundin

P

Persistent Organic Pollutants in the Puget Sound Ecosystem: Temporal Patterns in Excretion of POPs and Associated Endocrine Disruption in Free-Ranging Killer Whales

Bio

Jessica Lundin has a B.S. in Biomedical Science, and earned a Master's degree in Epidemiology from the University of Minnesota in 2006. In the years following, Jessica has worked as a Research Scientist evaluating the association of environmental and occupational exposures, such as PFOA, metals and pesticides, and adverse health outcomes like disease and cancer. Jessica is currently pursuing a Ph.D. at the University of Washington with a focus in Environmental Toxicology. Her research interests are to evaluate environmental contamination using biologic measures of wildlife populations.

Synopsis

The Puget Sound ecosystem has been riddled with human impacts. Exposure to persistent organic pollutants (POPs) is a primary risk factor for the endangered killer whale (*Orcinus orca*) population that subsists in these waters. POPs are toxic chemicals associated with adverse health effects including endocrine disruption. This project uses non-invasive biologic measurements to characterize the contamination level in this population, and to assess associated disruption of the endocrine system.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The Puget Sound ecosystem of Washington State has been riddled with human impacts. Exposure to persistent organic pollutants (POPs) has been listed as a primary risk factor for the endangered Southern Resident killer whale (*Orcinus orca*) population that subsists in these waters. POPs are a group of toxic chemicals associated with adverse health effects including endocrine disruption, neurotoxicity and immune system toxicity; the POPs being evaluated in this study include PBDEs, PCBs, DDTs, chlordanes, HCHs and HCB. The objectives of this research project are to use non-invasive methods to evaluate temporal patterns of toxicant excretion in top-level piscivores, and to assess associated disruption of the endocrine system through biologic measurements and an evaluation of reproductive success.

APPROACH

This study uses unique sampling methods to non-invasively measure endocrine indices and contaminant levels in a free-ranging killer whale population. Scat (fecal) samples are collected from killer whales through the employment of specially trained scat detection dogs. The Conservation Canines are able to locate samples floating on the water from as far away as a nautical mile from the whales, increasing sample size while decreasing sampling bias. Laboratory analyses of the samples include toxicant level quantification using GC/MS and enzyme immunoassays, hormone radioimmunoassays and DNA confirmation of species, individual and sex. The toxicant data will be used to assess the level of contamination in this endangered population. Predictive factors for variation in contaminant levels, such as gender, season and prey availability also will be evaluated. This study will contribute to the understanding of endocrine disruption associated with toxicant exposure by evaluating the relationship between toxicant and thyroid hormone levels measured from the same sample. Population-based and individual-based models will be used to evaluate the association of environmental contaminant levels and other biologic measures with population success.

EXPECTED RESULTS

The pollutants of interest are lipophilic; as such, these toxicants are generally stored in adipose tissue and released into circulation during times of nutritional shortage. The POP contaminate levels detected in the feces are expected to demonstrate an inverse relationship with the seasonal availability of salmon, as evaluated using salmon population estimates and concentration of fecal thyroid and glucocorticoid hormones (markers of nutritional stress). However, the expected inverse relationship between POP and thyroid hormone levels is expected to be non-linear. An accelerated decrease in the level of thyroid hormone is expected as the POP contaminant level increases due to endocrine disruption activity of the halogenated compounds. Lastly, population growth models adapted for this endangered population are expected to demonstrate an inverse correlation between reproductive success and POP contaminant level.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This study has the potential to have an important environmental and economic influence for the region by helping to inform the U.S. and Canadian governments, other scientists and non-government agencies. The measured outcome data from this study may be used to improve the effectiveness of remediation efforts and management approaches that would support priority Puget Sound ecosystem protection and restoration goals. Understanding POP contamination in Puget Sound is important for all who depend on the health of this ecosystem, including: subsistence-oriented consumer groups such as First Nations communities, sport-fishing families, and the public who rely on commercial fish markets, as well as killer whales, and other marine species.

Keywords: *persistent organic pollutants, PCB, PBDE, DDT, toxic chemicals, Salish Sea, Puget Sound, Southern Resident killer whales, endangered species, thyroid hormones, steroid hormones, detection dogs*

Pesticides and Toxic Substances
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Toxicology

Caroline Elizabeth Moore

P

Caenorhabditis elegans: A Novel Chronic Exposure Model to Evaluate Microcystins' Interference With Neurodevelopment

Bio

Caroline Moore received her B.S. in Biochemistry and Molecular Biology from the University of California (UC), Santa Cruz in 2009. She continued working at a small animal veterinary clinic and for the Department of Fish and Game, Marine Wildlife Veterinary Care and Research Center after graduation. She was accepted to the UC Davis School of Veterinary Medicine in 2010, and accepted into the dual degree program (D.V.M./Ph.D.) in 2010. She began as a graduate student in the Pharmacology and Toxicology Graduate Group in April 2010.

Synopsis

Microcystins are acute liver toxins produced by blue-green algae in rivers, lakes and fish worldwide, and adversely affect human health. There is insufficient information about the chronic effects of microcystins on any organ other than the liver. Because recent studies demonstrated microcystins' ability to enter the central nervous system, it is important to study microcystins' potential to cause neurotoxicity or interfere with neurodevelopment.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Chronic exposure to the potentially life threatening, ubiquitous microcystins (MCs) may interfere with neurodevelopment. Because MCs are acutely hepatotoxic and inhibit protein phosphatases *in vitro* and *in vivo*, MCs have a high potential to interfere with the regulation of normal neuronal function. The proposed research study will utilize a novel model system using *Caenorhabditis elegans* (*C. elegans*) to evaluate *in vivo* effects of chronic MC exposure on neurodevelopment.

APPROACH

To test the hypothesis that chronic exposure to MCs produces behavioral changes indicative of neurotoxicity in *C. elegans* by covalently binding protein phosphatases, the study will first determine if protein phosphatase (PP) activity is inhibited after chronic exposure of *C. elegans* to MCs and if levels of PP1, PP2A and PP2B are altered. PP1 and PP2A are known targets for MCs, while TAX-6, the sole calcineurin A subunit in *C. elegans*, shares high homology with human PP2B and is a potential indirect target if MCs alter intracellular calcium levels. Secondly, the study will determine if chronic exposure to MCs decreases chemotaxis similar to acute exposure, and evaluate several other behavioral endpoints. Thirdly, the study will screen protein phosphatase mutants for altered behavior and determine if chronic MC exposure exacerbates or ameliorates these protein phosphatase mutant strains' phenotypes to begin determining which protein phosphatases are targeted in *C. elegans*.

EXPECTED RESULTS

Exposure to MCs from egg to adult will cause neurological defects in *C. elegans* by targeting protein phosphatases, resulting in decreased levels of overall protein phosphatase activity but not altered expression of PP1, PP2A or PP2B. This will lead to a more pronounced decrease in chemotaxis behavior than noted in acute MC exposure due to prolonged alterations in sensory neuron signaling pathways. Along with the additional decrease in olfaction, hypersensitivity to osmotic changes and a loss of adaptation also are expected in chronically exposed *C. elegans*. As a result of defects in the regulation of serotonin-mediated reproduction pathways, the exposed strains will have a small body size and brood size, and a higher generation time and rate of egg laying in liquid compared to N2s. Exposed nematodes will be uncoordinated and have difficulties sensing changes in food availability or environment.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The protein phosphatases found as targets in *C. elegans* can be compared to homologous protein phosphatases of humans, leading to advances in MC neurotoxicity mechanisms. Exposing an *in vivo* model through its entire lifetime will represent a realistic exposure model of underrepresented populations continuously exposed from lakes and rivers with toxic blooms. If chronic exposure to MCs alters neurodevelopment *in vivo*, the accepted level of MCs in drinking water should be re-evaluated.

Keywords: *microcystin, blue-green algae,* Caenorhabditis elegans, *neurodevelopment*

Pesticides and Toxic Substances
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Civil/Environmental Engineering

Nancy Shiao-lynn Tseng

P

Biodegradation of Perfluorinated Compounds

Bio

Nancy Tseng received her undergraduate degree in Environmental Science with a minor in Environmental Health at the University of California, Los Angeles (UCLA) in 2010. Her previous research experience consists of: (1) analyzing diacetyl and acetoin and (2) determining the toxicity of titanium dioxide and zinc oxide nanoparticles to marine phytoplankton. She will earn her Master's degree in Civil and Environmental Engineering (CEE) from UCLA in 2011 and will continue to work towards a Ph.D. Her current research project will examine the biodegradation of perfluorinated compounds.

Synopsis

Perfluorinated compounds (PFCs) are man-made chemicals that are reproductive toxins, endocrine disrupters and carcinogens. PFCs are used in nonstick cookware, stain-repellants, aqueous fire-fighting foams and so forth. Due to their stability in the environment, PFCs are found globally as water pollutants. This project will investigate whether naturally occurring microbes can break down PFCs to nontoxic forms and will optimize environmental conditions to achieve the shortest cleanup times.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Perfluorinated compounds (PFCs) are a group of man-made, emerging contaminants that contain multiple carbon-fluorine (C-F) bonds, making PFCs highly stable and useful in commercial products such as aqueous fire-fighting foams (AFFFs), non-stick coatings, stain-resistant textiles, insulation, sealants and surfactants. These compounds have been found globally and are known carcinogens, reproductive and developmental toxins, and endocrine disrupters. This research project will investigate the biodegradation of PFCs, particularly perfluorooctanoic acid (PFOA) and perfluorooctanoic sulfonate (PFOS), to non-toxic forms by: (1) identifying the degradation capabilities of bacteria and fungi, (2) determining key enzymes involved in the biodegradation pathway, and (3) examining the effects of co-contaminants and environmental conditions.

APPROACH

This study will test the hypothesis that microorganisms capable of degrading halogenated compounds also can degrade PFCs. The first objective of this project will be to test the ability of (1) pure cultures of bacteria and fungi and (2) environmental microorganisms from PFC-contaminated sites to breakdown PFCs and fluoroaliphatic compounds. Environmental microorganisms may have acclimated to PFCs and can subsequently degrade PFOA and PFOS. The concentrations of PFCs and fluoroaliphatic compounds will be measured by liquid chromatography tandem mass spectrometry (LC/MS/MS), and a fluoride ion selective electrode will be used to measure the concentration of fluoride. In addition, biomass changes will be evaluated to determine whether any microorganism can use PFCs as an electron donor or electron acceptor. For those cultures that successfully degrade PFCs, the expression of biodegradative enzymes will be assayed and quantified using reverse-transcriptase quantitative PCR. The degradation products, determined by LC/MS/MS, will be used to propose a biodegradation pathway. Subsequently, the effects of environmental conditions and potential co-contaminants will be explored through the use of batch and flow-through column tests and through the use of experiments utilizing a range of co-contaminant concentrations.

EXPECTED RESULTS

The biodegradation of PFOA and PFOS is viable because (a) reductive defluorination is thermodynamically favorable and (b) peroxidase mechanisms have been shown to degrade other difficult compounds (e.g., lignin, pesticides, explosives and dyes). This study wants to prove that the biodegradation of PFCs can be mediated by microbes that are either known for degrading halogenated compounds or have been exposed to PFCs for long periods. Once the degradation of PFCs is confirmed, the enzymes utilized by those microorganism(s), the biodegradation rates and the metabolic pathways will be determined. This study also will characterize the effects of environmental conditions and co-contaminants on the biodegradation of PFCs because these influence the mobility and bioavailability of PFCs in addition to the composition and function of microbial communities.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The overarching goal of this research is to protect the environment and human health. Physical or chemical degradation technologies may be successful in the laboratory or in off-site reactors, but they can produce PFC-contaminated wastes, are expensive and require long-term pump-and-treat operations. In contrast, bioremediation techniques are easily utilized *in situ* and can drastically reduce PFCs in the environment without contaminated waste. This approach will prevent future risks from PFCs to humans, fisheries, wildlife and plants.

Keywords: *biodegradation, bioremediation, natural attenuation, perfluorinated compounds, PFOA, PFOS, PFC, bacteria, fungi, environment, pollution*

Pesticides and Toxic Substances
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EPA Project Officer: Gladys Cobbs-Green
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Judy Yu Wu

P

Effects of Neonicotinyl Insecticides on Honey Bee and Bumblebee Fecundity and Survival

Bio

Judy Wu received her undergraduate degree in Zoology from Humboldt State University (Arcata, California) in 2005. The following year, she was a Student Conservation Association intern working directly with USDA-ARS (Fort Lauderdale, Florida) assessing potential biological control agents for invasive weeds management. In 2007, she continued her interests in Entomology at Washington State University (Pullman, Washington) and began studying sub-lethal effects of pesticide residues in brood comb on honey bee health and development. She received her Master's degree from Washington State University in 2010. She currently is in a Ph.D. program at the University of Minnesota (St. Paul, Minnesota) investigating effects of neonicotinyl insecticides on honey bee and bumblebee health.

Synopsis

Bees provide crucial pollination services for natural and managed agriculture systems. In recent years, both natural and managed bee populations have declined. Neonicotinoids are systemic insecticides that can be expressed in all parts of a treated plant, including nectar and pollen. Bees become exposed to neonicotinyls while foraging and may return to their hive with contaminated resources. This project analyzes neonicotinyl exposure to honey bees and bumblebees focusing on reproductive effects, such as overwintering and egg-laying success, as well as physiological mechanisms.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The main objective of this project is to determine if and how neonicotinyl insecticide exposure contributes to honey bee and bumblebee colony decline. To do this, three research questions or focuses will be addressed. The first investigates how results obtained from laboratory bioassays, used to determine potential non-target risk, compare to responses from relevant field exposures. The second question will evaluate the over-wintering and reproductive success of honey bee and bumblebee queens exposed at known field-relevant concentrations of neonicotinoids. The third question will investigate possible physiological mechanisms responsible for observed behavioral effects of neonicotinyl insecticide exposure on bees reported in previous studies. The results of this project will be an important contribution and will improve the understanding of the effects of neonicotinyl insecticides on honey bee and bumblebee health, reproduction and survival.

APPROACH

The first stage is to complete several standard laboratory bioassays in which bees are individually fed a standard amount, 10 microliters, of test solution for each dose. A second set of bioassays will be completed in exactly the same manner except each bee will be fed 50 microliters of a test solution. Honey bees can collect 30 to 80 microliters of nectar while foraging, therefore comparing the responses in bees exposed at laboratory versus field relevant doses will improve the understanding of how accurate laboratory bioassays are in determining exposure risk to bees in the field. The second stage of this project is to determine field relevant exposure rates to use in experiments. This will be completed by treating plots of canola plants at various rates and analyzing the residue levels found in pollen and nectar of the treated plants. The experiments examining overwintering and reproductive success of honey bee and bumblebee queens will use the relevant field doses determined by chemical analysis from pollen and nectar collected from treated plants.

EXPECTED RESULTS

Comparisons between bioassays using laboratory standard and field relevant doses will improve the understanding of the effects of varying doses and concentrations of neonicotinoid exposure and may help elucidate discrepancies among reported results in various studies examining effects of neonicotinyl insecticides on bees. Using field relevant concentrations, determined by chemical analysis of nectar and pollen from treated plants, doses will provide more realistic responses to experiments and will strengthen the findings.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

These results will determine possible sub-lethal effects of neonicotinyl insecticides on honey bee and bumblebee reproduction and diapause previously not studied. These results also will be important in assessing the degree to which neonicotinyl insecticide exposure affects queen bee health, colony survival and whether current methods of risk assessment are sufficient in protecting pollinators.

Keywords: *honey bee, bumblebee, neonicotinyl, insecticide, reproduction*

Science and Technology for Sustainability

Environmental Entrepreneurship

Green Energy/Natural Resources Production and Use

Green Engineering/Building/Chemical Products and Processes/Materials Development

We will harness the sun and the winds and the soil to fuel our cars and run our factories....All this we can do. And all this we will do.

– President Barack Obama

Environmental Entrepreneurship

Green Energy/Natural Resources Production & Use

Green Engineering/Building/ Chemical Products and Processes/ Materials Development

Environmental Entrepreneurship

Science & Technology for Sustainability:
Environmental Entrepreneurship
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EPA Grant Number: FP917320
EPA Project Officer: Jose Zambrana
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Engineering

Regina Ruby Lee Clewlow

S

Examining High-Speed Rail and Aviation Systems Under Environmental Constraints

Bio

Regina Clewlow is a Ph.D. candidate in the Engineering Systems Division (ESD) at the Massachusetts Institute of Technology (MIT). She received her B.S. in Computer Science and M.Eng. in Civil and Environmental Engineering from Cornell University. Prior to her doctoral studies, she served as Executive Director for Engineers for a Sustainable World. At MIT, she has worked as a Research Assistant in the Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER). Her current research focuses on examining demand for high-speed rail and air transportation systems, and their performance under climate policies.

Synopsis

The continuous growth of global air transportation has significant implications for strategies to reduce CO_2 emissions from the transport sector. High-speed rail often is promoted as a lower-carbon alternative to air transportation; however, there is limited analysis of the complex interactions between HSR and aviation demand. This research examines the interaction of demand for high-speed rail and air transportation, and the long-range impacts of climate policies on these transportation systems.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The continuous growth of global air transportation has significant implications for strategies to reduce CO_2 emissions of the transportation sector. High-speed rail (HSR) is often promoted as a lower carbon alternative to air transportation, and is being considered in some nations as one component of a broader climate policy agenda. This research will examine the interaction of demand for high-speed rail and air transportation, and the long-range impacts of climate policies on these transportation systems. In doing so, the goal of this study is to develop an increased understanding of high-speed transportation options to aid transitions to a low-carbon economy.

APPROACH

This research will be carried out in three phases. First, an empirical analysis of intercity and airport-level demand for high-speed and air transportation in Europe, China and the United States will be conducted, utilizing general data analysis and econometric methods. Second, case studies of high-speed rail connections at airports in Europe and other regions will be conducted to examine the factors that enable cooperation, as well as to examine how transportation demand has been affected. Finally, climate policy analysis will be conducted to examine how different combinations of transportation investment and climate policies may impact future demand and CO_2 emissions of high-speed rail and air transportation.

EXPECTED RESULTS

This research will contribute to two key areas of inquiry: intercity passenger transportation demand analysis, and climate policy analysis in the transportation sector. This study will result in an improved understanding of intercity passenger transportation demand for high-speed transportation. By conducting a broad, international analysis of diverse markets on an origin-destination level, this research will contribute to bottom-up, origin-destination passenger demand analysis, in the context of air transportation and high-speed rail. Secondly, this research will result in an improved understanding of how climate policies might impact the transportation sector by developing an integrated approach to examine transportation investment and climate policies.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Understanding the interaction of air transportation and high-speed rail demand is critical for developing policies to reduce emissions in the transportation sector. This study will highlight complex factors that have impacted intercity demand in Europe and China, as well as examine how CO_2 emissions from aviation and high-speed rail have evolved over the past two decades. The results of this study will inform transportation and climate policies that will lead to more sustainable intercity transportation systems.

Keywords: *high-speed rail, aviation, transportation, climate policy, demand modeling*

Science & Technology for Sustainability: Environmental Entrepreneurship
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Science and Engineering

Micah David Fuller

S

Towards an Infinite-Range Vehicle: Roadway-Powered Electric Vehicles

Bio

Micah Fuller received a B.S. in Applied Math and a B.A. in Spanish from Southern Methodist University in 2001. He was the recipient of a full scholarship in 2001, receiving his M.S. in Applied Math in 2003. From 2003, he worked as an environmental consultant, project manager and air quality specialist for state and local government, and as an Adjunct Professor of Math in California. He returned to academia full-time in 2008 when he began the Ph.D. program in Transportation Technology and Policy in the Institute of Transportation Studies at the University of California, Davis. His research focuses on dynamic inductive power transfer for infinite-range, roadway-powered electric vehicles.

Synopsis

This research investigates the potential for an inductive power transfer system embedded in the roadway to support and foster rapid and widespread adoption of electric vehicles in advancement of sustainable transportation goals. Traffic demand modeling is employed under a GIS framework to map and analyze an optimized system in California. A time versus power demand profile is generated and used to simulate the system's impact on the electricity grid. Numerical modeling techniques are employed to investigate the impact of the RPEV system on pavement performance and service life and the impact of dynamic stresses on the embedded RPEV system. Key details of each system outlay will be determined based on financial, energy, societal and technical issues. A comprehensive solution based on feasibility criteria will be formulated and discussed in terms of its ability to provide comprehensive support to widespread EV adoption.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Exportation of American autopian society has helped create a world where fossil fuel-based motor vehicles threaten people around the globe and pose a significant challenge to global air quality and climate change goals. Electric vehicles have the potential to drastically reduce emissions; however, their adoption is limited by range and recharge issues. This research analyzes a comprehensive approach to solving range and recharge issues through roadway-powered electric vehicles (RPEVs) that can inductively be charged while moving along a roadway.

APPROACH

Traffic demand modeling and dynamic programming is employed under a GIS framework to map and analyze an optimized system in California. A time versus power demand profile is generated and used to simulate the system's impact on the electricity grid. Numerical modeling techniques are employed to investigate the impact of the RPEV system on pavement performance and service life and the impact of dynamic stresses on the embedded RPEV system. Key details of each system outlay will be determined based on financial, energy, societal and technical issues. A comprehensive solution based on feasibility criteria will be formulated and discussed in terms of its ability to provide comprehensive support to widespread EV adoption.

EXPECTED RESULTS

This research will demonstrate the potential for an inductive power transfer system embedded in the roadway to support and foster rapid and widespread adoption of electric vehicles in advancement of sustainable transportation goals. Anticipated results are expected to elucidate: how an infinite-range electric vehicle can become a reality by employing a comprehensive approach that alleviates range and recharge issues; how recent advances in wireless power transfer theory and power electronics technology can provide for a safe, economic and technically feasible system; how an inductive power transfer system can be just as efficient as plugging in and could replace the need for plugs (residential and public charging stations would all be inductive, utilizing the conductor beneath the vehicle for both moving and stationary charging); and that the electricity grid has the capacity to accommodate a full system deployment of infinite-range electric vehicles in California.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Widespread adoption of zero emissions vehicles is crucial to climate and air quality goals. Exacerbated by an affinity for fossil-fuel based vehicular travel and electricity generation, humans live in a world where particulate matter is estimated to cause 3.5 million cardiopulmonary mortalities per year and where overwhelming reductions in CO_2 emissions must be attained if the effects of climate change are to be limited. Roadway-powered electric vehicles have the potential to save millions of lives worldwide by significantly reducing tailpipe emissions, to meet climate goals by drastically curtailing CO_2 emissions and to usher in a new era of sustainable transportation fueled by renewable energy.

Keywords: *climate change, electric vehicle, inductive charging, range, recharge, infinite range, sustainable transportation, zero emissions, wireless power transfer, roadway powered electric vehicles*

Science & Technology for Sustainability:
Environmental Entrepreneurship
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EPA Project Officer: Jose Zambrana
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Risk Assessment

Catherine Michelle Hoffman

S

Enzymatic Wastewater Treatment: An Innovative Technology for Removing Pharmaceuticals and Personal Care Products

Bio

Catherine Hoffman received her B.S. in Environmental Engineering (with a minor in French) in 2009 from North Carolina State University in Raleigh, North Carolina, where she was born and raised. She then completed an M.S. degree in Engineering in 2011 in the Environmental and Water Resources Engineering program at The University of Texas at Austin. She currently is pursuing her Ph.D. in this same program. Catherine's research focuses on the development of an enzymatic treatment process to oxidize pharmaceuticals and personal care products in wastewater.

Synopsis

Chemicals from pharmaceuticals and personal care products (PPCPs) are not removed during municipal wastewater treatment. As a result, they are now routinely detected in natural waters and drinking water sources. Their presence in the environment is of concern because many PPCPs negatively impact aquatic life and ecosystems, and there also are concerns about potential human health effects. This research aims to develop an enzymatic treatment process for removing PPCPs from municipal wastewater.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The objective of the proposed research is to develop a sustainable and cost-effective enzymatic treatment technology that removes pharmaceuticals and personal care products (PPCPs) from municipal wastewater. This research also aims to address important questions about the proposed technology by tracking the fate and transformations of parent PPCP compounds, as well as their oxidation byproducts, throughout the treatment process.

APPROACH

The proposed research will be performed in four major phases. Phase 1 will evaluate two enzymatic treatment configurations for removing PPCPs from municipal wastewater primary effluent. Phase 2 will investigate the efficacy of inexpensive and sustainable mediator sources from food-processing wastes. Phase 3 will evaluate the removal of a mixture of PPCPs, as well as enzyme oxidation byproducts, in a bench-scale simulation of enzymatic treatment followed by conventional activated sludge and secondary clarification. Phase 4 will determine the fate of enzyme oxidation byproducts in conventional activated sludge followed by secondary clarification, considering biodegradation and adsorption as potential removal mechanisms.

EXPECTED RESULTS

Phase 1 is expected to determine an enzymatic treatment configuration that is practical for application in a wastewater treatment plant. Phase 2 is expected to identify an inexpensive and sustainable source of mediators. It is hypothesized that in addition to the removal of parent PPCP compounds from primary effluent, enzyme-catalyzed oxidation byproducts generated will be removed in subsequent biological treatment.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Successful development and implementation of enzymatic treatment of municipal wastewater could significantly reduce the release of PPCPs into the environment, and consequently reduce their presence in drinking water sources. Thus, not only would the health of aquatic ecosystems be improved, but human exposure to these chemicals through drinking water also would be reduced.

Keywords: *PPCPs, wastewater, enzymatic treatment, enzyme-catalyzed oxidation, laccase*

Green Energy/Natural Resources
Production and Use

Science & Technology for Sustainability: Green Energy/Natural Resources Production & Use
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EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Laura Anne Hoover

S

High Performance Membranes for Sustainable Production of Energy and Water

Bio

Laura Hoover received a B.S.E. degree from the Department of Civil & Environmental Engineering at Duke University in 2008. In 2009, she started Ph.D. work under Dr. Menachem Elimelech at the Yale University Department of Chemical & Environmental Engineering. In addition to her current project, she has studied transport in forward osmosis systems and the human and technical aspects of biosand filter use in rural Honduras. Her research pursues sustainable water and energy solutions for all people.

Synopsis

Forward osmosis (FO) and pressure retarded osmosis (PRO) hold great potential for sustainable production of drinking water and energy, respectively, from waste and renewable resources. Both are powered by osmosis and require semi-permeable membranes to separate solutions of different salinities. The lack of a suitable membrane has prevented widespread implementation of these technologies. This project advances FO and PRO by using novel materials and techniques to fabricate superior membranes.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research aims to increase the efficiency of energy and water production in pressure retarded osmosis and forward osmosis, respectively, by re-engineering the structure of the membranes used in these processes to diminish their generation of internal concentration polarization. Increasing the efficiency of these sustainable "engineered osmosis" technologies will make them more economically attractive and incentivize their commercial implementation.

APPROACH

Internal concentration polarization (ICP) is a performance limiting phenomenon that reduces the osmotic pressure difference, the driving force of pressure retarded osmosis and forward osmosis, across the semi-permeable membrane. Literature has established that the severity of ICP can be reduced by enhancing mixing, by increasing the porosity of the support layer of an engineered osmosis (EO) membrane, and by decreasing the tortuosity and thickness of the support layer of an EO membrane. A novel fabrication technique called electrospinning can produce networks of nanofibers that have extremely high porosity, customizable thickness and the strength and flexibility that are required to make robust membranes. Electrospun fiber alignment also can be tailored to enhance mixing. This project aims to investigate the use of electrospun fiber mats and other novel materials in the fabrication of ICP-minimizing, high performance membranes for pressure retarded osmosis and forward osmosis. Furthermore, models will be developed to determine the dependence of EO efficiency on customizable membrane properties to identify optimal conditions for fabrication of membranes for specific applications.

EXPECTED RESULTS

Successful completion of this research will produce high flux (water per area) membranes for forward osmosis and high power density (energy per area) membranes for pressure retarded osmosis. In addition, a more advanced model will be developed to guide optimization of membranes for specific applications with specific input streams, and previously underutilized streams, especially waste streams, will be identified that can become useful sources of energy and water through the application of engineered osmosis.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Pressure retarded osmosis can provide clean energy from renewable resources and waste, replacing conventional methods of energy production that harm human and environmental health and use non-renewable resources. Forward osmosis can provide a low-energy desalination alternative to conventional seawater desalination technologies, and it can lower the energy requirements and rate of waste production for select industries, including food processing and wastewater treatment.

Keywords: *renewable energy, drinking water, energy efficiency, pressure retarded osmosis, forward osmosis, engineered osmosis, salinity power, desalination, membrane, waste utilization, sustainability*

Science & Technology for Sustainability: Green Energy/Natural Resources Production & Use
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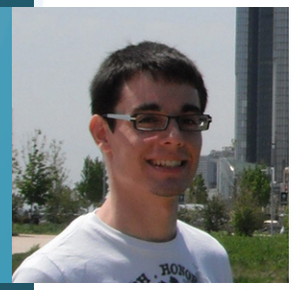
EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Policy



Chad Michael Huelsman

S

Elucidating Reaction Chemistry for the Treatment of Phenolic Compounds in Supercritical Water

Bio

Chad Huelsman received his undergraduate degree in Chemical Engineering from the University of Dayton in 2008. In the same year, he began his graduate studies at the University of Michigan in pursuit of a Ph.D. in Chemical Engineering. He completed his Master's degree in 2010. He has worked at the University of Dayton Research Institute, and he was a 2007 National Science Foundation, Research Experiences for Undergraduates Fellow at the University of South Carolina. He currently is researching reaction kinetics and pathways for the gasification of biomass model compounds in supercritical water.

Synopsis

Supercritical water gasification (SCWG) of biomass is an emerging green energy technology that mimics the conversion of ancient plant material into the natural gas reservoirs we rely upon today. Unfortunately, little is known about the chemistry leading to gas and undesirable, potentially harmful byproducts. This project investigates the products and reaction pathways associated with SCWG of biomass model compounds, providing vital information for an eventual environmental impact assessment.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This project investigates the supercritical water treatment of phenol and its derivatives under various processing conditions to explain the underlying chemistry of supercritical water gasification (SCWG) of biomass. The goal is to construct a reaction network from identified pathways and develop an accompanying chemical kinetic model that accounts for the reaction and formation of all experimentally observed species. Such a model will be essential for optimizing and assessing the environmental impact of this emerging green energy technology.

APPROACH

Phenol and phenol derivatives will be reacted under various processing conditions—temperature, water density, concentration and reaction time—and in quartz batch reactors to avoid any unintended catalysis by metallic reactor walls. Qualitative and quantitative analyses will be conducted post-reaction to determine the identities and yields of gas species and major byproducts. The effect of process variables on yields will be explained by kinetic and thermodynamic principles, which will be used to inform the reaction modeling. Reactant disappearance kinetics, temporal concentration profiles, and the Delplot methodology will be employed to discern the rank of intermediate species and to construct a reaction network comprising reactants, intermediates, and products and the chemical transformations linking them. A kinetic model based on the reaction network will be fit to experimental data to obtain information about the rates of all reactions occurring in the system. Dominant reactions will be identified, and a sensitivity analysis will reveal which reactions are most influential in the formation of a particular species.

EXPECTED RESULTS

Current results indicate that there are two main outcomes for phenol reacting in SCWG: decomposition to small, gaseous molecules and polymerization to larger, char precursor molecules that eventually lead to char buildup. One of the benefits of understanding the precise chemical pathways and kinetics responsible for these transformations is identifying ways to artificially promote gas formation and inhibit char formation. Expected results from this project include a reaction network and kinetic model, and these will be key for optimizing the process so that it is both economically and environmentally viable.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Using biomass as a green energy feedstock instead of non-renewable fossil fuels with net-positive carbon emissions offers immense environmental benefits, as does using supercritical water as a benign reaction medium for the processing of biomass instead of environmentally harmful organic solvents. Biomass SCWG is not without potential negative environmental impacts, however. Many byproducts with known human health and environmental effects—particularly polycyclic aromatic hydrocarbons—have been identified, and the information provided by this work will allow one to assess the environmental impact of these potentially harmful compounds as well as engineer ways to minimize their production.

Keywords: *biomass, green energy, supercritical water, gasification, hydrogen, reaction kinetics, pathways*

Science & Technology for Sustainability: Green Energy/Natural Resources Production and Use
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EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Terrestrial Systems
Ecology - plants and soils

Catherine Finlay Izard

S

Integrated Infrastructure Flow Assessment of the United States' Electricity Sector Under Climate Constraints

Bio

Catherine Izard is a joint Ph.D. student in the Departments of Engineering and Public Policy and Civil and Environmental Engineering at Carnegie Mellon University. She has a Master's degree in Industrial Ecology from the Norwegian University of Science and Technology and a B.S. in Geology and Geophysics from Yale University. Catherine's current research examines the impact of climate policy timing on the United States' electricity sector, estimating the rate of new capacity construction needed to meet emissions targets and identifying any possible limitations from short-term and material shortages.

Synopsis

Decarbonizing the United States' electricity sector may require a total restructuring of electricity infrastructure. This potentially implies an unprecedented amount of new construction, along with associated resource consumption. This research examines how climate change policy drives the rate of electricity construction and what that means for associated resource consumption. The results estimate the rate of new capacity construction needed to meet emissions targets and identify strategic energy-critical materials.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The combined pressures of climate change, energy security, supply and increasing demand will require rapid decarbonization (reducing the greenhouse gas intensity) of the electricity sector over the next 50 years. Large reductions of carbon dioxide emissions from the electric power sector will require a sustained commitment to new capacity construction; society is likely to have to maintain a high annual build rate of new capacity for decades. Unfortunately, there may be physical constraints on the rate at which electricity infrastructure can be built, due to massive inertia in the electricity sector and potential short-term shortages of energy-critical materials and labor. This project evaluates how several climate policy decision variables drive the rate of construction in the electricity sector. It then evaluates whether this construction is vulnerable to supply shortages in energy-critical materials and identifies low-risk infrastructure development pathways.

APPROACH

This project develops the Integrated Infrastructure Flow Analysis (IIFA) methodology, a flexible, integrated, systems based multi-criteria decision-making tool that can provide insights into the impact of climate policies on infrastructure. IIFA estimates the amount of new electricity capacity construction needed in the United States each year to simultaneously meet both demand and an exogenously specified GHG emission constraint as a function of the severity and timeline of those constraints and a specified new technology portfolio. IIFA then examines the implications of electricity capacity construction on energy-critical resource consumption in a global context to see if projected consumption is significantly larger than historical rates of production and consumption and thus might be vulnerable to supply disruption. The end result will be a portfolio of infrastructure development pathways that best avoid unintended roadblocks.

EXPECTED RESULTS

The project will develop IIFA, a decision-making tool that can identify pathways for sustainable infrastructure development over time. The research will identify carbon dioxide emissions reductions pathways and technology portfolios that could be successful at meeting emissions requirements in the U.S. electricity sector. The research also will identify potential material bottlenecks to decarbonization of the electricity sector, providing early notice of which energy-critical materials and/or technologies may require substitution, and thus allowing time for research and development to develop alternatives to costly scarce materials and identifying any metals that may be of strategic concern to the United States. This is especially important in the context of rapid increases in specialty metal consumption by the developing world as well as the increased use of geographically centralized scarce metal resources.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Climate change is a serious threat to the environment and human welfare, as the endangerment finding shows. This analysis identifies which electricity sector development strategies increase the chance of successful, rapid decarbonization. A system-wide analysis of the decarbonization of the U.S. electricity sector such as this one will identify impacts that are not apparent from smaller scale analyses, and has the possibility to inform national policy to mitigate them.

Keywords: *climate change, electricity, infrastructure, material flow analysis, resource management*

Science & Technology for Sustainability: Green Energy/Natural Resources Production & Use
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EPA Project Officer: Ted Just
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Science and Engineering

Debra Perrone

S

Spatial and Temporal Patterns of Water, Energy and Climate Relationships in a Decision-Making Context

Bio

Debra Perrone received her undergraduate degree in Civil and Environmental Engineering from Lafayette College in 2008. An active member of Lafayette's Engineers Without Borders chapter, she worked on water projects in rural Honduras. After graduation, she began the Ph.D. program in Environmental Engineering at Vanderbilt University, and has been a fellow of Vanderbilt Institute for Energy and Environment for the past 2 years. Her research focuses broadly on the water-energy nexus. She currently is working on exploring the spatio-temporal dimensions of U.S. water and energy resources.

Synopsis

Increased population and patterns of population density, economic growth and development all increase energy and water demands, and the impacts of a changing climate will exacerbate problems, especially given the strong interrelationships among water and energy use. Although demand for individual resources has been studied, a systematic evaluation of readily available data has not been undertaken to evaluate water-energy linkages. This project focuses on developing a comprehensive understanding of the complex tradeoffs and risks involved in water and energy management.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The main objectives of this project include: (1) identifying drivers of the water-energy nexus; (2) extracting information on historical and projected water-energy relationships; (3) highlighting potential climate change impacts on those relationships; (4) identifying patterns of demand-side competition for water; (5) creating a competitive water demand index to show demand-side stress on water; and (6) creating a decision-making and tradeoff-ranking tool for managers to assess competitive water demands, promote more effective management, increase efficiency and decrease consumption.

APPROACH

The basic premise for this dissertation is that spatial and temporal patterns that address a set of important questions about joint water-energy use can be established using multivariate analyses. The study will take advantage of data on climate (e.g., temperature, precipitation and humidity), water use, electricity use and production, population, economic activity and land use. The proposed research is to mine existing data to as great a degree as possible and perform exploratory data analyses to reveal spatio-temporal interrelationships and trends. The study also intends to explore potential changes in the future based on scenarios of climate change and management options. This information will be used to create a competitive water index for demand-side management of U.S. water resources and a decision-making framework to assist water managers in ranking the utility of their tradeoffs.

EXPECTED RESULTS

Anticipated results of this work include: (1) principal components that reveal how energy, water, climate and growth vary together; (2) clusters of variables and objects that reveal new spatio-temporal patterns important to the management of water and energy resources; (3) an understanding of how proposed climate change will impact or alter these interrelationships and patterns; (4) historic and forecasted competitive water demands; (5) a tool that incorporates multiple attributes to assist water managers in decision making and identifying tradeoffs; and (6) a sensitivity analysis to test the statistical precision of the results.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The results of this dissertation work will support the national information needs for stakeholders to co-manage water and energy resources. The purpose of this research is to reduce the information bottleneck associated with environmental management to provide stakeholders with relevant and contextualized information about the interrelationships between water and energy. The risk analyses will allow stakeholders to prioritize their needs and consider tradeoffs in management.

Keywords: *water-energy nexus, climate change, water resources, energy resources, exploratory data analysis, competitive water demands, resource management*

Science & Technology for Sustainability: Green Energy/Natural Resources Production & Use
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EPA Project Officer: Ted Just
Project Period: 9/1/2011 - 8/31/2013
Project Amount: $84,000
Environmental Discipline: Agricultural Engineering

Maxine Lynn Prior

S

Phototrophic Biofuel Production From Agricultural Waste

Bio

Maxine Prior attended Michigan State University for her undergraduate education where she received a Bachelor's degree in Chemical Engineering in 1994. After graduation, she accepted a position at Micron Technology in Boise, Idaho, where she expanded her knowledge to include semiconductor research and manufacturing. Her positions at Micron included Photolithography Engineer and Lead Photolithography R&D Engineer. She started a small business in 2009 to begin pursuing alternative energy research and began working on an INL-sponsored algal biofuel project in 2010 at Boise State University (BSU). She entered a Master's program at the University of Idaho in the spring of 2011 and is currently performing her thesis research at BSU.

Synopsis

Photosynthetic biofuels can be produced through utilization of nutrients found in agricultural waste streams. The resulting product is cost effective and has a net positive environmental impact. This project focuses on investigating high lipid producing algae species for biofuel applications, with emphasis on modeling predicted algal response (nutrient uptake, cell viability and lipid production) in agricultural wastewater.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Agricultural waste streams are rich in carbon, nitrogen, phosphorus and other unutilized micronutrients that often require significant costs for disposal. However, these nutrients can be readily taken up by algae through photosynthetic activity, producing a lipid product that can be converted into advanced biofuel (i.e., biodiesel or jet fuel). By combining the cultivation of high lipid producing algae with agricultural wastewater remediation, algal-based biofuel can be produced with a net positive environmental impact, reducing anthropogenic effects on surrounding waterways and ecosystems. The purpose of this research is to provide a model for expected algal species performance in specific agricultural waste streams for use in real life applications. The primary hypothesis is that an encapsulated algal system can provide a more densely populated biomass environment for maximum nutrient uptake and allow for biomass retention and easy lipid extraction without the need for costly downstream processing equipment.

APPROACH

Although algae can utilize a variety of waste streams for growth, this research will focus on dairy anaerobic digester (AD) centrate. The first phase of this work will investigate several promising algal species to determine their growth rates, lipid production and nutrient removal potential for the purpose of determining a model for algal species performance. Different algal species produce a variety of cellular lipids, including triterpenes and triglycerides; therefore, lipid yield will be assessed in the context of the applicability for biofuel production. The ability of single or multispecies mixtures to sequester nutrients in this application will be evaluated alongside lipid production rates to determine which algae species or consortium of species will be selected for further research. The second phase of research involves maximizing algal biomass retention and lipid extraction through encapsulation and simultaneous *in situ* lipid extraction. In this phase, the study will explore different encapsulation matrices, such as calcium alginate and/or silica-based substrates as a means of retaining a biomass while allowing diffusion of essential nutrients to the cell surface.

EXPECTED RESULTS

A quantitative model for algal growth, lipid production and nutrient uptake is expected to vary with each algal species based on characteristics displayed in the dairy waste stream; these are expected to be affected by turbidity, ammonia concentration and many other variables. The results will provide a quantitative model that may be used for future applications with predicted results. These parameters also will be used as inputs to a life cycle analysis model to evaluate the economic and greenhouse gas mitigation benefits of a secondary algae-based treatment system for agricultural waste from dairy farms.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Disposal of dairy waste is an environmental and financial strain for most dairy farms. This research is expected to showcase a feasible and environmentally positive biofuel and waste treatment model with expected beneficial economic implications for dairy farm operators. Reduction of dairy waste discharge can result in significant reduction of adjacent and downstream waterway eutrophication, resulting in an improved environmental impact.

Keywords: *biofuel, algae, dairy waste*

Science & Technology for Sustainability: Green Energy/Natural Resources Production & Use
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Sebastien H. Tilmans

S

Harvesting Energy From Wastewater Across Scales and Varying Economic Contexts

Bio

Sebastien Tilmans earned his Bachelor's degree in Civil Engineering at Cooper Union in New York City. Since then, he has spent 3 years building and monitoring energy-producing sanitation systems in rural communities in Panama. He currently is a graduate student of Civil and Environmental Engineering at Stanford University. He received a Fulbright Scholarship to work in Panama, and a National Defense Science and Engineering Graduate Fellowship to attend Stanford. His overarching passion is to transform society's waste streams from liabilities into assets for social, environmental and economic good. His research focuses on energy recovery from wastes in the United States and abroad.

Synopsis

Wastewater contains water, energy and nutrients, which are resources that this society currently procures at high economic and ecologic cost. Treatment plants around the United States are reaching their design life, while more than one-third of the global population has no access to sanitation services. This project uses case studies to quantify the potential to recover resources from wastes in various contexts, and the conditions under which resource recovery can support more sustainable infrastructure.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Wastewater contains water, energy and nutrients, all of which are resources that society currently procures at high economic and ecologic cost. With increasing water scarcity, rising energy prices and mounting concerns over climate change, resource recovery from wastewater is an attractive alternative to the current treat-and-discharge management system. Also, many treatment plants around the United States are reaching their design life and entering strategic planning processes, while more than one-third of the global population remains without access to sanitation services. This research will quantify the resources available to recover in wastes, and assess the conditions under which it is feasible and beneficial to do so. The results will help sanitation and water resource planners at home and abroad to develop the best waste management systems to advance societal, economic and environmental health.

APPROACH

One aspect of the project will use modeling software and case study data to analyze the energy balance of waste flows within communities and across different scales of decentralization (building-level, neighborhood-level or city/catchment scale). The other aspect is to use surveys, interviews and focus groups with community residents, regulators, utility personnel and other stakeholders to identify non-technical opportunities and constraints to resource recovery from wastes. The research will use case studies from the United States and sites in developing countries to calibrate the model and derive guiding principles for planners and designers.

EXPECTED RESULTS

This research will help spur a shift among wastewater infrastructure planners from focusing on waste management to concentrating on resource recovery. It will highlight methods to produce value from wastewater, and identify effective strategies for doing so. Specifically, the research will underscore the potential to generate energy from wastewater, a subject that is typically eclipsed by discussions of water reuse. As strategies are implemented for water reuse, the technical and economic parameters around energy recovery from wastewater will change dramatically. The analysis tools developed in this research will serve to pre-test plans and technologies within large integrated systems, informing policy and planning decisions for optimal environmental and economic benefits.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

In the United States, resource recovery from wastewater can help preserve the public health benefits of aging infrastructure by providing new revenues and lowering the cost of waste management. It can restore ecosystem services by reducing withdrawals from streams and aquifers, and by creating sources of sustainable energy and materials. In developing countries, resource recovery can help finance the installation and operation of new systems, delivering health and dignity to billions of people who are currently without service. This research will provide decision makers with some of the tools they will need to realize these opportunities.

Keywords: *resource recovery, wastewater, infrastructure, water, sanitation, developing countries, water reuse, energy, water-energy nexus, decentralized treatment*

Green Engineering/Building/Chemical
Products and Processes/Materials Development

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Civil/Environmental Engineering

William O. Collinge

S

Evaluating the Impact of High-Performance Buildings Using Advanced Life Cycle Methods

Bio

Bill Collinge received his Bachelor's degree in Civil and Environmental Engineering (CEE) at the University of Pittsburgh in 1997. The following year, he was an AmeriCorps volunteer, helping to reduce childhood lead poisoning in low-income areas of Pittsburgh. Bill worked for 10 years as a practicing civil engineer from 1999 to 2009, obtaining his Professional Engineer's license in 2004. He is currently a Ph.D. candidate in the Sustainability and Green Design group in the CEE Department at the University of Pittsburgh, focusing on dynamic temporal and spatial environmental impacts of commercial and institutional buildings, including indoor environmental quality effects. Prior to his current project, Bill completed a separate research project involving the implementation of biodiesel fuel in a public transportation maintenance fleet.

Synopsis

The goal of this research is to improve life cycle assessment (LCA) methods for commercial and institutional buildings, by including indoor environmental quality and dynamic changes that may occur during the building's lifetime. A core model of energy and materials use and indoor environmental quality will be coupled with background data, related to changing spatial and temporal patterns of life cycle impacts. The model will be tested under different future scenarios to evaluate design decisions.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The goal of this research is to demonstrate an improved life cycle assessment (LCA) method that adequately portrays whole-building impacts to the natural and built environments, such that it is of value to practitioners in the architecture, engineering, construction and management community. The explicit hypothesis for this work is that incorporating both indoor environmental quality and dynamic temporal and spatial life cycle data into environmental assessments of buildings will have a significant effect on environmental performance scores. Testing this hypothesis entails constructing an LCA model that incorporates both of these aspects, and using case studies to compare results obtained using this model to results from current models.

APPROACH

This research will be split into two main tasks. The first task will develop a mathematical model and computational framework to enable dynamic life cycle assessment. Time series of life cycle inventory (LCI) emissions and resource consumption factors will be developed from available historical data sources and projections (e.g., EPA emissions inventory trends, BEA industry data, DOE-EIA energy consumption data and projections). Additional time series of life cycle impact assessment (LCIA) characterization factors will be obtained from the literature or developed from available models. This information will be coupled with information from available building models and plans to generate time series for a variety of building use scenarios against evolving environmental (e.g., regulations, ambient concentrations) and industrial (e.g., technology mixes, fuel sources) backgrounds. The second task will develop a building-specific indoor environmental quality (IEQ) component to be embedded into the dynamic LCA model. The model will be constructed using the results of previously published studies and will take into account building parameters affecting indoor air quality (IAQ) and other IEQ elements (e.g., thermal comfort, ventilation and lighting), and will be validated by taking sensor measurements within the initial case study building, the Mascaro Center for Sustainable Innovation (MCSI) building at the University of Pittsburgh. IEQ effects on human health will be integrated within the existing LCA methods for human health impact assessment, while effects on the economic bottom line (e.g., productivity) will be integrated within a life cycle cost framework.

EXPECTED RESULTS

Results of the integrated modeling effort will provide several levels of improvement to the current state of LCA practice for buildings. The inclusion of dynamic temporal and spatial life cycle data will provide a more accurate framework for assessing the impacts of different building design and operation decisions over future building lifetimes, thus enabling more effective decision-making. The IEQ results will help to identify the tradeoffs or synergies between environmental impacts to building occupants and the impacts to the general population that result from building operations and energy demands.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Having a flexible, state-of-the-art model to simulate building lifetime environmental impacts will inform building designers and operators of the full environmental implications of building designs, enabling them to better evaluate multiple bottom line scenarios. In addition, the direct comparison of indoor and outdoor effects related to buildings has the potential to be scaled up to the entire building sector, where it may enable better regulatory decision-making by prioritizing the areas of highest impacts.

Keywords: *life cycle assessment, dynamic life cycle assessment, indoor environmental quality, indoor air quality*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Isaac R. Emery

S

Expanded Life Cycle Assessment of Biofuels: Mass Flows and Greenhouse Gas Emissions During Bioethanol Production From Switchgrass and Sweet Sorghum

Bio

Isaac Emery graduated from Whitman College in 2005 with a degree in Biochemistry, Biophysics and Molecular Biology. He worked as a Research Scientist in Cardiology at the University of Washington Medical Center, before beginning a Ph.D. in Ecological Sciences and Engineering at Purdue University in 2008. At Purdue, Isaac mentors incoming graduate students and conducts research on the environmental impacts of bioenergy technologies, developing a model to inform biofuel feedstock supply and land management decisions. In addition to his graduate work, he volunteers with a small team, creating an online game that will reward participants who "go green" in real life.

Synopsis

Renewable energy is expected to have little environmental impact, but replacing fossil fuels with agricultural energy systems, like ethanol, can have unintended consequences. Life cycle assessment of energy technologies can help avoid negative impacts. By measuring carbon and nitrogen flows during biofuel production, focusing on crop production and storage, this project will assess greenhouse gasses and water quality. This data will be integrated with existing research and policy tools.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Ethanol and other biofuels are currently the most promising candidates to replace a large fraction of U.S. gasoline consumption, but producing feedstocks on a large scale raises issues of land use, greenhouse gas emissions and water quality. This project addresses these concerns by developing a methodology for mapping carbon and nitrogen flows during biofuel feedstock production, and assessing the effects of crop storage on the life cycle impacts of biofuels.

APPROACH

Switchgrass and biomass sorghum grown at Purdue University will be stored as bales and silage to generate the data necessary for a life cycle assessment. Controlled laboratory storage experiments will be used to determine direct emission rates of the greenhouse gasses CO_2, CH_4 and N_2O, as well as the effects of temperature and moisture on biomass loss during dry and wet storage. Larger scale, 12-month field storage trials of bales and silage will be conducted to validate laboratory data under realistic storage conditions. Results of these studies will inform a life cycle assessment of ethanol production from switchgrass and biomass sorghum, conducted by modifying the GREET model to accommodate biomass storage.

EXPECTED RESULTS

Dry matter loss during storage is expected to range from 3 percent to 10 percent at low moisture to 10 percent to 35 percent at high moisture, and 5 percent to 15 percent in silage. Modeling storage at a bioethanol facility will increase substantially the greenhouse gas and water quality impacts of the fuel through a combination of increased production requirements, direct greenhouse gas emissions and changes in feedstock composition during storage. Ensiling of sorghum bagasse is expected to have a greater impact than dry bale storage of switchgrass, but the net impact may be reduced by the high yield and sugar fraction of sweet sorghum. The methodology developed will provide a framework for future research, enabling the assessment of many more scenarios and feedstocks by guiding data collection of storage studies to fit into the life cycle assessment framework.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Identifying nutrient flows between the field and the fuel production plant is necessary to reduce sources of greenhouse gasses and other pollutants in the biofuel logistics chain, ensure that essential nutrients are recycled to the soil, and to better understand the relationships between crop fertilization, biomass storage and greenhouse gas emissions. Biofuel production cannot be considered sustainable if it contributes substantially to eutrophication or generates greenhouse gas emissions similar to fossil fuels. By identifying areas where losses of nutrients and dry matter are most significant, this research may reveal where "best practices" could greatly reduce the environmental impact of biofuels from agricultural feedstocks.

Keywords: *biofuels, biomass storage, greenhouse gases, nitrogen, life cycle assessment, biomass logistics*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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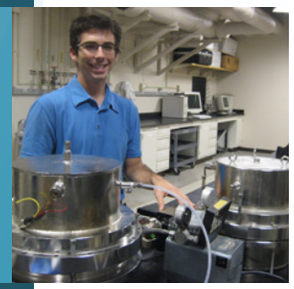
EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering



Elliott Tyler Gall

S

Porous Materials in Indoor Environments: Investigating Transport and Reaction Mechanisms of Pollutant Removal to Porous Indoor Surfaces

Bio

Elliott Gall received his B.S. in Environmental Engineering from the University of Florida in 2006. For the following year and a half, he was employed as a consulting engineer with CDM, Inc. In 2009, he received his Master's degree from the University of Texas (UT) at Austin. In 2010, he began the Ph.D. program in Civil Engineering at UT. His research concerns reactions of gaseous pollutants with surfaces in the indoor environment. Currently, he is researching the interaction of porous materials and indoor pollutants, and modeling their impact on household energy use and indoor pollutant levels.

Synopsis

Exposure to air pollution is dominated by what humans breathe indoors. Ozone is an important outdoor air pollutant; however, recent research indicates that indoor exposure to ozone and its reaction byproducts may contribute to health effects previously correlated with outdoor ozone. Some indoor materials can react with ozone, while producing benign byproducts and requiring no energy input. This project investigates promising materials to reduce human exposure to ozone and harmful byproducts.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Human exposure to air pollutants is dominated by what is breathed indoors, and indoor materials can act as important sources and sinks of pollutants. This research investigates the potential for utilizing the large surface area of materials to remove indoor air pollution through reactive uptake processes. This research project will build on this idea by focusing investigations on porous materials, which can increase the surface area of the indoor environment by orders of magnitude, and may act as significant long-term sinks of indoor air pollution.

APPROACH

This work will investigate and characterize heterogeneous ozone chemistry with indoor surfaces, specifically pertaining to the determination of opportunities for increasing indoor ozone removal to surfaces. This will be accomplished by characterizing fundamental physical and chemical parameters, which will allow for more accurate modeling of ozone removal to porous building materials. The effect of physical properties like porosity, material thickness and material contamination on overall ozone removal will be determined using an experimental apparatus constructed for the project. With this information, a fundamental transport and reaction model will be developed and validated with chamber ozone concentrations measured. A sensitivity analysis will be performed to determine which material parameters have an outsized effect on overall ozone removal. The relative importance of fluid mechanic conditions and material properties will be assessed for whole-house modeling of ozone concentrations under a variety of airflow and indoor material scenarios.

EXPECTED RESULTS

The information determined in this investigation will result in a more detailed understanding of the mass transfer and transformation processes occurring during reactive removal of ozone with indoor surfaces. The determination of effective surface areas and porous diffusion time scales through indoor materials may help resolve disagreement between established mass-transfer models and experimental data, as well as comparisons across studies. This also will allow predictive modeling, which can more accurately assess the benefit of changing physical parameters of indoor materials, such as an increase in material thickness or porosity. Furthermore, the determination of the dependency of ozone removal on specific material parameters will aid in the theoretical design and/or fabrication of dedicated indoor pollutant removing materials.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Reducing indoor ozone concentrations is important because 120,000,000 Americans live in ozone non-attainment areas, and with people spending 90 percent of their time indoors, a large portion of exposure to ozone occurs indoors. Targeting remediation of indoor environments with pollutant removing materials also will allow specific sub-populations to utilize passive removal in particularly efficient ways. Sensitive populations, to whom EPA's outdoor ozone standards are intended to protect, may utilize specific materials to reduce trigger pollutants like ozone. Furthermore, pollutant removing materials investigated in this research can purify air with no direct energy inputs, improving indoor air quality without increasing the already substantial energy burden of buildings.

Keywords: *indoor air quality, indoor ozone, porous materials, low energy air cleaning*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Public Health Sciences

Conrad Alexander Gosse

S

Environmentally Preferable Pavement Management Systems

Bio

Conrad Gosse received his undergraduate degree in Ocean Engineering from Virginia Polytechnic Institute in 2003. He worked building environmental design support tools at the nonprofit GreenBlue, and also completed a Master's degree in Urban and Environmental Planning at the University of Virginia. To further consider transportation and the built environment, he completed a Master's degree in Civil and Environmental Engineering at the University of Virginia, and is now pursuing doctoral research there on the environmental optimization of pavement maintenance planning. Conrad's career goal is to help realize a more concrete connection between land use and transportation planning as the real key to a more sustainable and livable future.

Synopsis

Infrastructure, and consequently policies that create and sustain it, shapes peoples' daily lives. In the context of climate change, one third of total emissions are the direct result of transportation in this country, and so Conrad chose to apply himself in that area. Engineering certainly has a role to play in reducing transportation impacts through things like more efficient vehicles and roadway networks; however, these efforts may ultimately run counter to environmental goals by incentivizing greater per capita consumption of passenger miles. This project will build tools that integrate environmental considerations along with conventional objectives, such as cost and performance, to create a tool to optimize pavement maintenance planning, minimizing both cost and environmental impact, while preserving the vast public investment in roadways. Conrad hopes to combine his engineering and planning training in a policy position focused on the broad adoption of integrated infrastructure planning and preservation.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Many departments of transportation (DOTs) rely on pavement management systems (PMS) to plan maintenance operations by identifying schedules that maximize overall network condition subject to cost constraints. PMS do not typically incorporate environmental considerations, despite ideally being situated in the decision making process to balance performance and environmental goals. This work seeks to develop a practical and computationally tractable algorithm that will allow DOTs to add a third (environmental) dimension to the two implicit in current practice: cost and performance.

APPROACH

The large, multi-objective and discrete design space of pavement maintenance planning is well suited to genetic optimization. The first phase of the work applied a genetic algorithm and basic model of greenhouse gas (GHG) emissions from paving operations to the interstate highway pavements in a western district of Virginia as a proof of concept. This framework will be extended to incorporate a more comprehensive and geographically aware life-cycle estimation of roadway maintenance GHG emissions by employing the numerical power of computer graphics hardware to allow a fully stochastic treatment of uncertainty, allowing the selection of robustly optimal maintenance plans by DOTs.

EXPECTED RESULTS

Preliminary results showed a strong correspondence between economic expenditure and GHG emissions, making reducing environmental burden compatible with budget concerns. Optimized maintenance plans were found that both exceeded the performance of current DOT practice in the study area despite lower costs and reduced GHG emissions. Incorporating more specific sources of GHG emissions into the model, such as those of vehicles delayed by work zones, should allow the optimized results to further improve on current practice by exploiting site-specific information that would be impractical to consider without a framework such as that proposed here. Asphalt pavements also are highly recyclable, but only within the closed loops of individual construction firms. Stochastic simulation of this market will provide valuable insight into DOT contract bidding policies to encourage environmentally preferable outcomes.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Maintenance of existing paved infrastructure impacts human and environmental health in numerous ways, including GHG emissions, airborne particulates, noise, emissions of volatile organic compounds and impacts to aquatic environments from both silt and potential surfactant leaching from emulsified asphalt coatings, to name a few. This research seeks to use computational optimization to minimize the amount of maintenance work performed in the first place, and to incorporate an explicitly environmental objective in maintenance planning to capture and minimize impacts that would otherwise be externalized in a traditional cost-based asset management program.

Keywords: *pavement management systems, green roads, sustainable design, greenhouse gas control*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Aquatic Ecology and Ecosystems

Jessica Kaminsky

Sanitation Networks in Developing Communities

S

Bio

Jessica Kaminsky received her undergraduate degree in Civil Engineering at Rice University in 2004. After graduation, she worked for CH2M HILL and was heavily involved in volunteer activities for the nonprofits Engineers Without Borders and Water for People. In 2010, she began the Ph.D. program in the Mortenson Center in Engineering for Developing Communities at the University of Colorado at Boulder. Her research focuses on improving water and sanitation technology in developing communities worldwide.

Synopsis

Household sanitation systems, like septic tanks, are one of the most common sources of groundwater contamination in the United States. Although some of these failures are due to poor design, many are instead caused by inadequate maintenance and operation. To address this issue, this project quantifies the social networks that impact sanitation systems. This new understanding of how human factors impact sanitation technologies will enable an improvement in sanitation infrastructure sustainability.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research targets the problem of the impacts of inadequate operations and maintenance for onsite wastewater treatment systems. By seeking to quantitatively understand how social networks impact wastewater infrastructure, this research will make a transformative contribution to environmental and public health protection. By targeting often-ignored developing (non-sewered) communities, this research directly will address pollutant emissions from the more than 26 million U.S. onsite systems.

APPROACH

This research uses social network analysis and case study methods to quantify mathematically, gendered social network characteristics and develop targeted training programs to improve onsite wastewater treatment system sustainability.

EXPECTED RESULTS

The premise of this research is that an understanding of the social networks that impact wastewater infrastructure can be used to assess how human/social factors affect onsite system performance, thereby enabling improvement in sanitation infrastructure sustainability. Therefore, this research will describe how human factors impact household sanitation systems, and will leverage this new understanding to develop targeted training programs for technology users.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Improved sanitation sustainability will reduce infrastructure cost through increased lifespan of equipment, reduce the global disease burden by reducing vectors for waterborne illness, enable recovery of valuable resources such as nutrients and water, and improve environmental protection by reducing untreated waste discharge. An understanding of social networks will have positive impacts on each of these important issues.

Keywords: *sanitation, onsite wastewater treatment, developing communities, social network analysis*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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EPA Project Officer: Jose Zambrana
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering

Erinn G. Ryen

S

Expanding Industrial Ecology by Applying Community Ecology Principles and Developing Diversity Metrics for Sustainable Product Systems

Bio

Erinn Ryen received her undergraduate degree in Applied Economics and Business Management from Cornell University in 1991. Shortly thereafter, she completed a Master's in Public Administration from Syracuse University (1993) and a Master's in Science from the State University of New York College of Environmental Science and Forestry (1995). Erinn has more than 15 years of work and volunteer experience, starting as an intern at the White House Office on Environmental Policy and continuing as an environmental consultant, environmental specialist and longstanding member of her town's Conservation Board. Currently, Erinn is a member of the Sustainability Oversight Committee for Brighton, New York. After spending several years at home with her two children, Erinn started the Ph.D. program in Sustainability at the Rochester Institute of Technology (RIT) Golisano Institute for Sustainability. Her research currently focuses on applying biological ecology concepts to industrial product and material systems.

Synopsis

This research project will pioneer new metaphors and models for industrial ecology based on fundamental principles of community ecology borrowed from biological systems. Specifically, this project investigates how materials and products of environmental importance are structured at the community scale and managed with respect to environmental goals. Test cases initially focus on opportunities for environmental improvement of information and communication technology products.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Industrial ecology provides a holistic framework that can provide insight on complex relationships between industrial and ecological systems. However, practical implementation and application of industrial ecology has been constrained by the same complexity that gives the field its desired breadth and comprehensive nature. Therefore, an opportunity exists to uncover new concepts in biological ecology with relevance to industrial systems and potentially more practical feasibility. This research project will: (1) formulate a conceptual framework based on principles of community ecology; (2) develop community scale metaphors and models to better understand the structure of industrial product systems; and (3) test and refine community models related with cases studies in information communication and technology (ICT) product systems.

APPROACH

Research will be conducted in three integrated phases. Phase One constructs a conceptual research framework based on community ecology principles identified by literature review. Phase Two identifies and describes relevant metaphors and models from biological systems, focusing on community structure. Relevant terminology from biological systems is translated to industrial ecology, emphasizing how concepts relate to the test case. In Phase Three, models are developed and refined with test cases in ICT. A Diversity Flow Model investigates the association between the evolving structures of ICT systems and economic factors that drive end of life reuse and recycling. This model combines product/material flow analysis, biological ecology diversity indices and multi-criteria optimization. A Geospatial Diversity Model extends the first model's methodology using geographic information system (GIS) software. Maps of material diversity and recovery value densities visualize end of life material stream changes over time, as well as sensitivity to market prices and larger impacts such as technology shifts and legislation.

EXPECTED RESULTS

Achieving the research objectives will demonstrate that the community ecology perspective can provide valuable insight to understanding stability and sustainability of ICT product systems. Manufacturers and recyclers can use the tools to design products and recycling technologies that optimize material recovery and minimize resource consumption, pollution and waste generation. Resulting data also can be used to inform policies, such as electronic waste regulation, and prioritize which material or product system to evaluate for life cycle impacts.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Understanding how product systems are structured can help preserve sustainable systems, protect against undesirable disturbances, or destabilize existing unsustainable structures to transition towards a sustainable path. Achieving the research objectives will further environmental protection by maximizing recovery of valuable and scarce materials, minimizing environmental impacts of toxic substances, and reducing embodied energy losses from ICT and other products. In addition, this research may help decision-makers modify existing recycling and emission control technologies to accommodate new material streams.

Keywords: *diversity, sustainability, industrial ecology, community structure, ICT products*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
Scripps Research Institute (CA)
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EPA Grant Number: FP917296
EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Chemistry

Peter San Thuy-Boun

S

Catalytic Arene Functionalization for Applications in Industrial Waste Reduction and Pollution Sequestration

Bio

Peter Thuy-Boun received a B.S. in Chemistry with a minor in Mathematics in 2010 from the University of California, Los Angeles (UCLA). As an undergraduate, he spent 3 years working on the organometallic chemistry of lanthanides and actinides in Professor Paula Diaconescu's laboratory and 1 year working on bioinorganic iron-nitrosyl chemistry in Professor Lijuan Li's laboratory. Currently, he is a graduate student at The Scripps Research Institute developing catalytic chemical reactions in Professor Jin-Quan Yu's laboratory.

Synopsis

This project aims to contribute to the area of chemical waste reduction by means of efficient chemical reaction development. Using emerging direct C–H functionalization techniques, this project will address the selective construction of widely important aromatic molecules. Rational catalyst design and mechanistic investigations will guide the development of such reactions to reduce associated chemical waste, especially for ton-scale industrial processes.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Substituted aromatic molecules are important building blocks especially common in medicine, plastics and new functional materials. Important as these compounds are, the methods employed for their construction are still indirect and often involve multiple purification steps, which can lead to the generation of large quantities of chemical waste. This research aims to streamline the synthesis of substituted aromatics through the development of catalytic direct functionalization processes.

APPROACH

Initially, this research will focus on elucidating Ni's competency for catalytic C–H functionalization chemistry. Once a catalytic manifold is established, a set of ligands will be designed and screened to probe Ni's propensity for meta/para C–H coordination and activation. Subsequently, ligands able to promote meta/para coordination will be applied under C–H functionalization conditions to achieve the selective substitution of aromatic molecules.

EXPECTED RESULTS

As Ni catalyzed C–H functionalization chemistry is relatively unexplored, it is expected that a bulk of the initial effort will be geared toward identifying compatible substrates and coupling moieties. It is likely that the substitution of aromatic compounds first will be developed using directed ortho-metalation. After a thorough understanding of this process is achieved, the research will focus on achieving meta/para activation with the application of ligands. Enhanced reactivity is anticipated with the rational modification of such ligands. A study of the structure and electronics of these ligands will provide insight for further studies potentially opening new avenues of investigation.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Substituted aromatic building blocks are commonly utilized on an industrial scale. As such, the development of new greener methods for their construction has the potential to reduce the need for environmentally harmful, waste-intensive purification procedures. More efficient aromatic substitution processes also will lower the cost and broaden the diversity of building blocks used to construct medicines, biomedical materials, consumer plastics, organic light emitting diodes (OLED), organic solar cells and metal-organic frameworks (MOF) among other things. Because new functional materials such as gas sequestering MOFs rely on the availability of diverse aromatic building blocks, green technology also will benefit from more efficient aromatic functionalization methods.

Keywords: *chemistry, catalysis, green chemistry, green processes, aromatic functionalization, C-H functionalization, C-H activation*

Science & Technology for Sustainability: Green Engineering/Building/Chemical Products & Processes/Materials Development
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EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Materials Engineering

Ronald Joseph Warzoha

S

Nanoenhanced Phase Change Materials for Advanced Energy Storage

Bio

Ronald Warzoha received his undergraduate degree in Mechanical Engineering from Villanova University in 2008. The following year, he graduated with his Master's degree in Mechanical Engineering from Villanova University with a concentration in Thermal-Fluid Systems. He also was selected as the college's graduate student Medallion recipient and co-founded an interdisciplinary social and environmental entrepreneurship program on campus. In January 2010, he began the interdisciplinary Engineering Ph.D. program at Villanova University. His research involves investigating nanoenhanced phase change materials for thermal energy storage in renewable energy systems applications, as well as determining the fundamental transport mechanisms for thermal energy storage in nanoenhanced phase change materials. He currently is investigating the impact of different types, sizes and amounts of nanostructures on the thermal properties and behavior of phase change materials with respect to bulk thermal energy storage.

Synopsis

The thermal management of renewable energy systems and portable, handheld electronics is fast becoming one of several critical issues threatening to impede the progress of obtaining higher efficiencies in renewable energy systems and reducing power consumption from fossil fuels. The objective of this research is to investigate the potential of, and subsequently optimize, phase change materials with embedded nanostructures for advanced thermal energy storage in the aforementioned applications.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The low efficiency of most power systems presents a formidable problem for increased energy distribution, and subsequent consumption, in the future. A substantial portion of this low efficiency can be attributed to waste heat. In these systems, heat often is used as a means for power generation. In this case, a greater temperature or an extended generation time corresponds with a more efficient system. A good example might be a solar thermal power system, where longer exposure to heat (or heat retention) might lead to an increase in a system's capacity to deliver power and an increase in its efficiency. Other systems require a reduction in a steady operating temperature (computers, cell phones, etc.), which often is accomplished by using thermal management systems that must consume power to operate effectively (i.e., fans, pumps, jets, etc.). In either case, the thermal management solutions have continuously required more power consumption as a result of the increased heat transfer constraints. This research project examines the role that phase change materials play in reducing the amount of power required to operate renewable energy power delivery systems and thermal management solutions. Phase change materials have the ability to store thermal energy over extended periods of time without requiring additional power (depending on the mass, volume, heat load and latent heat of fusion values), but suffer from a low thermal conductivity and thus not all of the PCM's storage capacity can be used when in its raw form. Recent technologies used to increase the thermal conductivity of phase change materials have been fins and foams, which increase total thermal storage capacity. Although some have been successful, many of these designs do not comply with the constraints placed on modern power delivery systems and electronics. Preliminary studies suggest that the addition of several types of nanofibers greatly enhance the thermal energy storage time of PCMs while also complying with the aforementioned constraints. This research now will look into the effect of several different parameters of nanostructures on the thermal energy storage time and delay to steady conditions, including length, diameter, type and weight fraction. Once this has been determined, the nanofibers will be separated using two techniques (surfactants and adding an acidic charge) to determine the most effective way to keep nanofibers separated in the liquid phase. This will complete an effort to create a phase change material that is capable of storing an adequate amount of thermal energy for a variety of power profiles and thus, result in a thermal storage material that is economically feasible to implement in applications to reduce overall power consumptions, including, building walls (increase HVAC efficiency), solar thermal systems and modern electronics.

APPROACH

The first stage of the research will use standard experimental techniques to characterize the thermal conductivity, specific heat and latent heat of PCMs embedded with a variety of different types, sizes and amounts of nanostructures. The thermal conductivity will be measured using a transient hot-wire apparatus, while the specific heat and latent heat of each composite material will be measured using a differential scanning calorimeter. These properties will be vitally important in determining both the reason for enhanced thermal storage capacity in nanocomposite PCMs and for optimization in later stages of the research. The second stage of this research is to determine the effect of each of these same parameters (nanostructure type, size and amount) on the thermal energy storage capacity in adiabatic thermal containment units, which are most like those that would be implemented in renewable power deliver systems or modern electronics packaging. Finally, this research will investigate the potential for stabilizing the nanofibers and prevent them from aggregating and separating from the PCM after several thermal cycles by examining the effect of a common surfactant vs. an acidic soak, which forms a positive charge on each nanostructure and fosters coulomb repulsion. After this research is completed, it is expected that an economically feasible and sustainable design will be accomplished such that the PCM becomes a driving force for a reduction in power consumption or increase in power capacity for these systems.

EXPECTED RESULTS

These engineered materials will allow thermal engineers to design for precise energy storage performance based on PCM type, nanoadditive type, amount, length and diameter, heat source orientation, nanoadditive suspension and geometric configuration. Although the NovaTherm Laboratory has identified the preliminary potential for nanoadditives in PCMs, the work presented here will investigate and quantify this potential with a substantially broader scope. Upon completion of this work, the design of energy storage modules finally will be possible and recognized as economically feasible with the implantation of nanostructures.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research will examine the effect of nanostructure type, amount and size on the thermal energy storage capacity of phase change materials for a reduction in energy consumption in some applications (electronic packaging, building walls for HVAC efficiency enhancement, etc.) and for an increase in energy retention in others (solar thermal power systems, etc.). When PCMs become viable candidates for adequate thermal energy storage in these applications, a large portion of fossil fuel consumption, and overall power consumption, can be substantially reduced as the PCM requires no power to store the thermal energy.

Keywords: *thermal energy storage, phase change materials, nanostructures, renewable energy systems*

Tribes and American Indian/Alaska Native/Pacific Islander Communities

Humankind has not woven the web of life. We are but one thread within it. Whatever we do to the web, we do to ourselves. All things are bound together. All things connect.

– Chief Seattle, 1855

Tribes and American Indian/Alaska Native/ Pacific Islander Communities

Tribes and American Indian/Alaska Native/ Pacific Islander Communities
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EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2013
Project Amount: $84,000
Environmental Discipline: Life Sciences

Jason Eric Baldes

T

Application of a Holistic Process to Improve Community and Ecological Health by Reintroduction of Plains Bison to the Wind River Indian Reservation

Bio

Jason Baldes received his undergraduate degree in Land Resource Sciences from Montana State University in 2010 and is pursuing a graduate degree in Land Resources and Environmental Sciences. On the Wind River Indian Reservation, Jason is utilizing a community-based participatory process and the Native Science Field Center to promote youth involvement in a buffalo restoration effort, by promoting tribal resource management, native food traditions, ecological integrity and cultural revitalization.

Synopsis

Health disparities on the Wind River Indian Reservation have increased with removal of traditional food sources used for millennia. The buffalo provided a vital source of sustenance, and were a cornerstone to the existence of many other species. Ecological integrity diminished with the decimation of the buffalo, as did cultural values, language and spirituality. This project utilizes a community-based approach to improve environmental and health conditions for residents on the reservation.

OBJECTIVE(S)/RESEARCH QUESTION(S)

In Indian country, there are predominantly higher rates of diabetes, heart disease and other health-related problems from removal of native food traditions. Additionally, assimilation policies have led to loss of cultural values, language and ecological knowledge that was once passed down through successive generations. By reintroducing buffalo to the Wind River Indian Reservation, members of the Eastern Shoshone and Northern Arapaho tribes will once again have access to additional food sources that improve lives, health, spirituality and ecological integrity of the Reservation. This project will utilize a community-based approach to restoration by incorporating existing programs and youth education to raise awareness and provide ownership within the community for the effort.

APPROACH

The first component of research will be an inventory of edible and medicinal plants utilized by Shoshone and Arapaho people in the areas identified for buffalo reintroduction to compare vegetation biodiversity after reintroduction takes place. Traditional ecological knowledge provided from tribal elders will be bridged with youth involved with the Wind River Native Science Field Center, Five Buffalo Days, and Diabetes programs to foster support and understanding for cultural, nutritional and ecological importance of buffalo restoration. Additional steps in the project will consist of identifying potential source herds that are genetically reputable and disease free. The introduced herd of buffalo will be managed as wildlife under the Wind River Tribal Game Code, and be consistent with current species conservation strategies to maintain genetic diversity.

EXPECTED RESULTS

With establishment and access to buffalo, overall health of Indian people will be improved, plant biodiversity will increase, and ecological and historical conditions will be restored. Linking elders with youth in an effort to restore a cultural icon improves the ability of children to make choices without disregard to traditional belief ways and customs. By establishing genetically reputable and disease free buffalo, preservation of the buffalo genome is acknowledged and potentially will provide source animals to other tribes or entities who wish to establish conservation herds. The animal will provide a valuable source of nutrition to elders, youth and community members during feasts and ceremonies. Health disparities, spirituality, cultural and traditional values, and strength of Shoshone and Arapaho people will improve with the presence of the buffalo.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This project will set a precedent for what management of buffalo can be on tribal lands. The animal is central to the culture of the Shoshone and Arapaho people and is integral to many other tribes struggling to hold on to cultural belief ways, ceremonies, language and customs. With the highest rates of diabetes, heart disease and nutrition-related problems of any ethnic group in America, Native Americans are at a crossroads in the effort to improve lives of future generations. Ecologically, there is no animal that can replace what the buffalo was to the landscape, and in Indian county, human health protection and buffalo preservation are not mutually exclusive, they are intertwined.

Keywords: *Plains Bison, buffalo, reintroduction, restoration, health disparities, diabetes, heart disease, native food traditions, traditional ecological knowledge (TEK), ecological integrity*

Tribes and American Indian/Alaska Native/ Pacific Islander Communities
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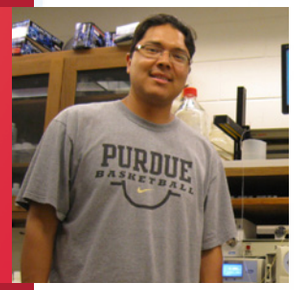
Project Period: 8/1/2011 - 7/31/2013
Project Amount: $84,000
Environmental Discipline: Environmental



Michael Zane King

Evaluating Sources of Chemical Pathways of Aerosol Production on the Southern Ute Indian Reservation and Navajo Nation Using Isotopic and Geochemical Analysis

Bio

Michael King received his undergraduate degree in Environmental Science from Haskell Indian Nations University in 2005. The following year, he was employed with the Southern Ute Indian Tribe (SUIT) as an Air Quality Analyst and then became the Tribe's Air Quality Specialist. He provided technical air monitoring management and assisted with the development of program components for the SUIT (Clean Air Act) Title V Part 70 Operating Permits Program to capture major sources of air pollution. After working 4 years in the field of tribal air quality control, he began the M.S. program in the Department of Earth and Atmospheric Sciences at Purdue University. His research focuses on evaluating chemical pathways of aerosol production on the Southern Ute Indian Reservation and Navajo Nation using isotopic and geochemical analysis.

Synopsis

This project will examine the stable isotope composition of atmospheric aerosols collected on the Southern Ute Indian Reservation and Navajo Nation to provide insight into the sources of nitrogen oxides (NO_x) and the oxidation pathways that convert NO_x into nitrate. Results from this project will be used to assist Tribal air quality programs in the Four Corners region to develop policies and regional planning that will improve air quality and protect human health.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Increased emissions of nitrogen oxides (NO_x) as a result of the development of oil, gas and coal resources in the Four Corners region of the United States have caused concern for area American Indian tribes that levels of ozone, acid rain and aerosols or particulate matter (PM) may increase on reservation lands. NO_x in the atmosphere plays an important role in the formation of these pollutants and high levels are indicators of poor air quality, and exposure to them has been linked to a host of human health effects and environmental problems facing today's society. Nitrogen oxides are eventually oxidized in the atmosphere to form particulate nitrate and nitric acid, which falls to earth's surface by way of dry or wet deposition. In the end, it is the removal of NO_x from the atmosphere by chemical conversion to nitrate that halts this production of oxidants, acid and aerosols. Despite the importance of understanding atmospheric nitrate production, there remains major deficiencies in estimating the significant key reactions that transform atmospheric NO_x. This project will examine the stable isotope composition of particulate nitrate ($PM_{2.5}$-PM_{10}) collected on the Southern Ute Indian Reservation and Navajo Nation to provide insight into the sources of NO_x and the oxidation pathways that convert NO_x into nitrate on these reservation lands.

APPROACH

The first part of the research will be to request archival $PM_{2.5}$ and PM_{10} filters for the years 2007 and 2009 to be released from the Southern Ute Indian Tribe (SUIT) and Navajo Nation to the Department of Earth and Atmospheric Sciences at Purdue University. Both the SUIT and Navajo Nation operate PM monitoring networks as part of the U.S. EPA PM national monitoring network. Nitrate (NO_3) from the filters will be extracted, purified and concentrated using preparative ion chromatography (IC). In addition, trace metals such as lead, copper, nickel and zinc and major cations such as calcium, magnesium and sodium will be measured by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The total isotopic composition of the nitrate will be carried out using the denitrifier technique, in which the nitrate is added to a solution containing a unique strain of denitrifying bacteria that convert NO_3 into gaseous nitrous oxide (N_2O). The N_2O is collected using a headspace extraction device and gas chromatograph before being passed over a gold reaction tube where the N_2O is quantitatively converted into nitrogen (N_2) and oxygen (O_2). Isotopic analysis on the product N_2 and O_2 will be done using a continuous flow isotope ratio mass spectrometer (IRMS) to determine the $\delta^{15}N$, $\delta^{18}O$, and cap $\delta^{17}O$ values. Lastly, the Regional Atmospheric Chemistry Mechanism (RACM) photochemical box model will be used to predict nitrate cap $\delta^{17}O$ values, which would then be compared to the observed data obtained from the PM filters. The RACM model will be initialized using air quality data obtained from the SUIT and Navajo Nation air quality programs. All isotopic measurements of nitrate extracted from tribal PM filters will be carried out at the Purdue Stable Isotopes Laboratory under the direction of Professor Greg Michalski. All data collected from tribal PM filters will be shared with tribal air quality programs, and biannual research updates will be presented to tribal air quality staff and Tribal Council members.

EXPECTED RESULTS

The 1990 Clean Air Act (CAA) amendments authorized the EPA to allow Indian tribes to implement CAA programs in Indian Country under the Tribal Authority Rule (TAR). However, most tribes lack the resources needed to develop comprehensive air programs. Of the four tribes in the Four Corners region, the Navajo Nation and SUIT have established air quality programs under the TAR and have "Treatment as State" status, which allows tribes to monitor ambient air as well as develop federally enforceable air quality regulations to reduce air pollution on reservation lands. The data and results from this project will provide tribes with additional insight into the atmospheric processes that control air quality over tribal lands. This project will provide the SUIT and Navajo Nation insight into the sources of NO_x and chemical pathways that convert NO_x into nitrate over tribal lands. Isotopic analysis of nitrate will provide a baseline assessment to assist tribal air quality programs with their continual development of policies and regional planning efforts to improve air quality and protect the health and welfare of tribal members and residents.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The delegation of authority from the EPA to the Navajo Nation and forthcoming SUIT to implement operating permitting programs and regulations to reduce air pollution on reservation lands are the first of its kind in Indian Country. With ambient air quality measurements in the Four Corners region indicating ozone levels approaching "non-attainment" with existing National Ambient Air Quality Standards (NAAQS), it is extremely important that tribal air quality programs continue to actively participate with air quality regulatory agencies to cooperatively reduce regional air pollution. Both the Navajo Nation and Southern Ute Indian Reservation are home to numerous minor sources and several major sources of air pollution in the Four Corners region. This project may help in assessing how expected NO_x emissions from power plants and increases in oil and gas exploration on these reservation lands might impact local tribal air quality, specifically ozone and particulate concentrations. The results can then supplement tribal air quality permitting programs and assist tribes with their continual development of policies and regional planning efforts to improve air quality and protect human health and the health of future generations to come.

Keywords: *particulate matter (PM), $PM_{2.5}$, PM_{10}, nitrogen oxides, ozone, Tribal Authority Rule, NAAQS, nitrate, stable isotopes, Clean Air Act*

Tribes and American Indian/Alaska Native/ Pacific Islander Communities
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EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Geology (Hydrology)

Heidi Elizabeth Mehl

A Cultural Ecology of Riparian Systems on the Prairie Band Potawatomi Nation: Understanding Stream Incision, Riparian Function and Indigenous Knowledge to Increase Best Management Plan Adoption

Bio

Heidi Mehl completed a Bachelor's degree in Biology, and a Master's degree in Global Indigenous Nations Studies at the University of Kansas. Heidi's Master's thesis, "Water Quality Issues Facing Indigenous People in North America and Siberia," examined ways to situate scientific information within indigenous worldviews to help communities become informed decision makers about the quality of their water resources. She has monitored water quality and hydrologic functioning on the Potawatomi Reservation in Kansas, and conducted several grant-funded projects in the Altai Republic in Siberia. Through her work as a hydrologist at the U.S. Geological Survey, she participated in numerous studies and co-authored three reports and one fact sheet. Heidi currently is studying Fluvial Geomorphology in the Department of Geography at Kansas State University. Her dissertation research focuses on stream incision and riparian function, and integrating traditional ecological knowledge into scientific evaluations to increase best management plan adoption.

Synopsis

Agricultural runoff is a major water quality impairment that is difficult to manage. Cost-effective solutions for tribes, like the Prairie Band Potawatomi Nation, require an increased understanding of the function of streambank vegetation in filtering nutrients and bacteria in stable and unstable stream channels. The results of this research will be used to create a land management outreach program in collaboration with the tribe that integrates scientific knowledge with indigenous knowledge.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Widespread adoption of best management practices (BMP) is often difficult to achieve, especially in the face of poorly understood traditions and cultural attachments. This study will investigate stream incision and riparian function on the Prairie Band Potawatomi Nation (PBPN), and assess indigenous knowledge of riparian and stream ecosystem services with respect to water supply and quality. The fundamental goal of this research is to combine advanced understandings of riparian hydrology and water quality function in the Great Plains with a sound understanding of indigenous nature-society value systems to design a successful water quality BMP outreach program.

APPROACH

This research will use stream gages, shallow groundwater wells and piezometers to investigate the effect of stream incision on riparian water tables, and the effectiveness of Great Plains riparian forests to remove sediment, nutrients and bacteria from overland and subsurface flow. Channel incision is a well-documented problem on the streams flowing through the PBPN. The lowered elevation of incised stream channels is likely producing a net lowering of the riparian water table, potentially reducing baseflows and limiting riparian forest growth and/or restoration. There also is evidence that lowered water tables impair the ability of riparian areas to filter nutrients. These data will be complemented by interviews and surveys conducted with tribal officials, elders and community members of the PBPN, designed to understand traditional river and riparian knowledge and cultural beliefs and practices related to management of streams and riparian areas. Combined, this information will lay the framework for a water quality BMP outreach program that integrates scientific data with specific local knowledge and traditions to increase the chances of program adoption.

EXPECTED RESULTS

An increased understanding of riparian hydrology and water quality dynamics will contribute to the literature on riparian buffers and their ability to mitigate pollution, as well as inform the PBPN of water and water quality dynamics on their lands. The enhanced cultural understanding of human-riparian interactions and perceptions will enhance greatly the ability of state and federal regulators to work with the PBPN and other indigenous nations to improve water quality. The potential positive impacts could extend well beyond the PBPN reservation boundaries to other tribes and communities in the Midwest facing similar issues, and even to similar international efforts. At a minimum, this research will inform land management practices and BMP adoption from a cultural standpoint and help bridge the gap between science and adoption of BMPs, resulting in an overall improvement of water quality on the PBPN.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The ability of riparian areas to filter pollutants like nutrients and sediment is well-documented; however, understanding of the effect of channel incision on this function is lacking. There also are very few studies documenting the ability of riparian areas to filter bacteria and pathogens from overland runoff. The information gained from this study will inform land managers and engineers to the effectiveness of riparian areas to improve in-stream water quality. Using this information to design a successful BMP outreach program will result in improved water quality on the PBPN and downstream, which will greatly benefit ecological communities and the health of the PBPN who hunt, fish and swim in local streams.

Keywords: *riparian, channel incision, water table, nutrients, sediment, bacteria, pathogens, indigenous, Prairie Band Potawatomi, best management practices, BMP, water pollution, traditional knowledge, community-participatory methods*

Tribes and American Indian/Alaska Native/ Pacific Islander Communities
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EPA Project Officer: Jose Zambrana
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Mechanical Engineering

Len Edward Necefer

Navajo Nation's Electrical Grid Modernization With Renewable Energy Sources

Bio

Len Necefer is a member of the Navajo Nation, representing the Tachiinii and Nakai Dine Clans. Len is a graduate of the United World College of the American West where he was a Davis Scholar. He received his undergraduate degree in Mechanical Engineering from the University of Kansas in May 2011. In the fall of 2011, Len will pursue Ph.D. study at Arizona State University, focusing in Mechanical Engineering and Public Policy. His research focuses are Energy Infrastructure, Electric Vehicles and Renewable Energy and Engineering Policy in Indigenous Communities. Currently, he is researching the impact of electrified vehicles on the power transmission capabilities of the Navajo Nation. This research will provide a basis for future development of energy infrastructure on Native American reservations.

Synopsis

Renewable energy and electrified vehicles will require a "smart" power distribution network on the Navajo Nation. Coal power currently is provided to high population centers, including southern California. Increased demand and renewable energy will require an update of the energy grid. Tribal Sovereignty and Energy Resource Agreements govern grid development. The current state and direction of the high-voltage power transmission will be assessed towards reducing air pollution through renewables.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The objective of the research is to analyze the impact Smart Grid technology and renewable energy sources will have on air quality of the Navajo Nation. The research will aim to structure an approach coinciding with Tribal Energy Resource Agreements (TERAs) and unique cultural considerations for implementing smart grid technology while meeting future demand from electrified vehicles.

APPROACH

The relationship between tribal, state and federal governments on issues relating to infrastructure and renewable energy projects needs to be further investigated. The relationships between tribes and states can change regionally. The Navajo Nation alone covers three states, meaning that unique relationships exist between each. An exhaustive literature review will be conducted on energy policies on Native American reservations. In addition, state and federal government energy policies have a significant influence on the reservation policy and will be included in the review. Unique cultural considerations exist aside from policy; for most Navajos culture is formed around the connection with the land. Future projects and policies must consider this reality in their formation, in addition to unique tribal government relationships. Benchmarking the results of renewable energy infrastructure projects in low-income and American Indian communities is a necessary step in this project. In addition, benchmarking existing renewable energy projects with respect to how electrical transmission is addressed is needed. The benchmark projects will not be solely on reservation land, instead throughout the United States. Modeling and analysis of the Navajo Nation's grid and power generation capacity with renewable sources and electrified vehicles will be conducted to understand its capabilities. This will require analyzing the location of current and proposed projects and what transmission capacity would have to be added to accommodate them.

EXPECTED RESULTS

The results from this research will provide more insight into the formation and factors that should be considered when American Indian tribes form energy policies. Tribal Energy Agreements have to consider the dynamic tribal-federal relationships that will provide a framework for future projects. The cultural realities that exist on the Navajo Nation would provide a common context that other federally recognized tribes could assess future energy policies. The results will provide state, federal and Tribal EPA agencies with a better understanding of how environmental protections can be implemented with increased renewable energy infrastructure projects. Analysis on the current state of the Navajo Nation's infrastructure will demonstrate its limitations and capabilities. The analysis collected may show that the current state of infrastructure is sufficient for future renewable energy projects. This outcome still would allow for a better understanding of how the development policy led to the current state. Another possibility exists that certain areas of the reservation are more able to support renewable energy projects than others. This result could point towards developing regional solutions and policies. Future energy legislation and academic studies could use these results as a basis for how Tribal Energy projects have developed. Information regarding policy shortfalls in past legislation will dissuade certain approaches. Yet more importantly, policy successes that have contributed to the betterment of Indian Reservations can be used as a template for future projects. This research also will serve as guidance for the Navajo Nation government as it pursues renewable energy in the next century.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The research will specifically aid in the implementation of the Clean Air Act and the Clean Water Act protections of the Navajo Nation through reduced emissions from Coal power generation. Smart Grid and renewable energy resources will allow for future power generation on the Navajo Nation in place of expanded coal power.

Keywords: *Smart Grid, renewable energy, Tribal Energy Resource Agreements, Clean Air Act, Navajo Nation, climate change, air pollution effects*

Tribes and American Indian/Alaska Native/ Pacific Islander Communities
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EPA Project Officer: Jose Zambrana
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Social Ecology

Daniel Reid Sarna-Wojcicki

Revitalizing Watershed Management Through Karuk Indigenous Ecological Knowledge

Bio

Daniel Sarna-Wojcicki received his undergraduate degree in Ecology from Columbia University in 2005. After working for 3 years as an Editorial Assistant for the global health journal *PLoS Neglected Tropical Diseases*, he began a Ph.D. program in Environmental Science, Policy and Management at the University of California, Berkeley. His research focuses on institutional design for resolving conflicts over water and land use at the watershed scale. He currently is researching collaborative watershed management institutions in the Klamath River Basin of Northern California.

Synopsis

This project examines institutional mechanisms for translating the Karuk Tribe of Northern California's indigenous ecological knowledge and resource management practices into official watershed management policy. Through document analysis, participant observation and interviews with community members and federal, state and Tribal representatives, this research evaluates institutions' ability to effectively represent Karuk values and knowledge in watershed management policy and practice.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This project examines the effectiveness of institutional arrangements for translating the Traditional Ecological Knowledge (TEK) and indigenous management practices of the Karuk Tribe into formal watershed management policy in the Karuk's aboriginal territory of Northern California. Through a detailed investigation of the processes through which Karuk representatives and community members participate in official knowledge production and decision making, this research aims to illuminate barriers to knowledge integration, conflict resolution, community participation and government-to-government collaboration in watershed management. Watershed management policy that accurately embodies the Karuk Tribe's values and knowledge in a culturally appropriate institutional framework is vital to the restoration of ecosystem processes and water quality conditions in the region as well as to the culture, health and self-governance of the Tribe.

APPROACH

The first stage of research aims to map out the various legal, political and administrative mechanisms that underwrite the translation of Karuk TEK and indigenous management practices into official watershed management policy. This complex institutional landscape includes Basin-wide deliberative forums and task forces, Sub-basin planning committees, water quality control plans, local watershed councils, court decisions, endangered species habitat protection plans and memoranda of understanding between the Karuk Tribe and various federal and state resource management agencies. Through document analysis, participant observation in public consultation and comment sessions, and interviews with community members and federal, state and Tribal representatives, this research will evaluate institutions' ability to effectively represent Karuk values and knowledge in watershed management policy and practice.

EXPECTED RESULTS

Through observing the process of translation in a number of forums, this research aims to elucidate a set of "due-process principles" to inform the uptake of Karuk TEK and guide Karuk participation in resource management. By illuminating barriers to effective tribal participation and meaningful translation of Karuk values and knowledge, this project works towards developing an institutional framework that will allow the Tribe to restore the ecological foundations of their cultural heritage and community health. Such a framework will contribute to federal, state and local resource management agency efforts to resolve longstanding resource conflicts in the Klamath Basin and fulfill Tribal participation mandates. In addition, developing culturally appropriate forums that can mobilize this rich source of local environmental knowledge supports efforts to restore ecological function in a region with seven major rivers listed as water quality impaired and several terrestrial and aquatic species listed as endangered or threatened.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Encompassing terrestrial and aquatic ecological processes, the watershed provides an integrated unit of resource management. The Karuk Tribe's vision of eco-cultural restoration pushes integrated resource management even further by focusing on the intricate connections between fire disturbance regimes, vegetation dynamics, erosion, run-off, in-stream conditions and fish habitat and in highlighting the importance of such ecological processes to cultural integrity and community health. In investigating how institutions can overcome conflicting knowledge, value and right claims to manage resources collaboratively, sustainably and effectively, this research aims to contribute to academic and policy debates regarding the design of resilient and democratic institutions capable of facing 21st Century resource management challenges.

Keywords: *traditional ecological knowledge, cultural resource management, indigenous rights, social-ecological resilience, institutional analysis*

Water Quality

Coastal and Estuarine Processes

Hydrogeology and Surface Water

For many of us, water simply flows from a faucet, and we think little about it beyond this point of contact. We have lost a sense of respect for the wild river, for the complex workings of a wetland, for the intricate web of life that water supports.

– Sandra Postel
Last Oasis: Facing Water Scarcity, 2003

Water Quality

Coastal and Estuarine Processes

Hydrogeology and Surface Water

Coastal and Estuarine Processes

Water Quality: Coastal and Estuarine Processes
University of Hawaii (HI)
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EPA Grant Number: FP917273
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Marine/Environmental Science

Daniel William Amato

Effects of Submarine Groundwater Discharge as a Vector for Sewage Effluent on Hawaiian Coral Reefs

Bio

Daniel Amato received his undergraduate degree in Biology with a minor in Chemistry from the University of Vermont in 2004. In 2005, Daniel accepted a position as a research assistant/graduate student at the University of Hawaii (UH) working with endemic marine algae. Upon receiving his M.S. in Marine Botany from UH in 2009, he was admitted to the Ph.D. program, and currently is a doctoral candidate. His current research focuses on the interaction between sewage pollution, groundwater and coral reef ecosystems.

Synopsis

The continued decline of coral reefs and coastal water quality is a global phenomenon. The effects of sewage discharge in coastal areas are well known and can lead to drastic changes in the health and ecology of marine environments. The purpose of this study is to investigate the extent and impact of sewage pollution on Hawaii's coastal reefs. Using an interdisciplinary approach, the connection between terrestrial sewage injection, groundwater and coral reef health will be examined.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The primary purpose of this investigation is to determine the extent and impact of sewage pollution on Hawai'i's coral reefs. Two hypotheses will be tested: (1) Sewage effluent isotope tracer levels (δ15N) will be greater in areas proximal to wastewater treatment plants (WWTPs) utilizing injection wells compared to areas of low anthropogenic impact; (2) Sewage effluent isotope tracer levels (δ15N) will have a positive relationship with measures of submarine groundwater discharge and algal photosynthetic performance.

APPROACH

This study will focus on coastal areas adjacent to state operated WWTPs utilizing injection wells to determine if submarine groundwater discharge (SGD) is a vector for sewage effluent discharge to the coastline. An interdisciplinary, multi-tracer approach employing bioassays, biological surveys and chemical water analysis will be used to test these hypotheses. The productivity and chemical composition of marine algae will be analyzed to determine the impact of sewage-derived pollution on coastal reefs. Water samples collected from coastal aquifers and the near-shore water column will be analyzed for stable isotopes (C, N, O), radio isotopes (Rn, Ra) and elemental content to calculate hydrogeochemical processes such as SGD flux, coastal mixing rates and nutrient loading at specific sites in Hawai'i. With the help of the Polynesian Voyaging Society, local educators, students and community groups, a statewide survey will be performed in Hawai'i to identify areas of sewage discharge to the near-shore environment. Crew members of the voyaging canoe, Hōkūle`a, will assist volunteers with the collection of water quality and reef health data using GPS, waterproof cameras and benthic quadrats, digital water quality meters and algal collection protocols during a statewide sail.

EXPECTED RESULTS

The results of this study will identify locations in the Hawaiian Islands where sewage effluent is discharged on coastal reefs. It is expected that low δ15N values will be found in macroalgal tissues in areas of low development and anthropogenic impact, and high δ15N values will be found in areas of high development and anthropogenic impact. The highest δ15N values are likely to be measured in areas proximal to WWTPs utilizing injection wells or developments using cesspools. Algal tissue δ15N levels, growth rates and photosynthetic performance are expected to be elevated at impacted sites due to sewage-derived nutrient loading. It is expected that algal growth rates and photosynthetic performance will have a positive relationship with estimates of SGD flux and a negative relationship with salinity. SGD flux estimates and water analysis will be used to calculate nutrient loading at specific sites. One important conclusion that may arise from this investigation is a direct connection between terrestrial injection of sewage and biological processes in the coastal ocean. By utilizing an interdisciplinary approach including hydrological and algal physiological methodology, this study will be able to conclude that SGD is a vector or underlying process, facilitating this transmission of sewage pollution from injection wells to the marine environment.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This study has great potential to highlight the extent and impact of sewage pollution on Hawaiian coral reefs while elucidating the interconnection between coastal aquifers and marine ecosystems. These results have important implications for the permitting, management and treatment of wastewater and sewage disposal in coastal areas. Most importantly, this study has the potential to educate and actively involve thousands of underrepresented community members in scientific research and ocean conservation in Hawai'i.

Keywords: *sewage, pollution, injection, effluent, marine, algae, groundwater, SGD, invasive, water, wastewater, aquifer, Hōkūle`a, discharge*

Water Quality: Coastal and Estuarine Processes
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EPA Grant Number: FP917376
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Microbiology

Erin Michelle Symonds

Development of Pepper Mild Mottle Virus as a Bioindicator of Fecal Pollution in Commercial Shellfish Beds

Bio

Erin Symonds received a B.A. in Biology and Environmental Science from the University of Virginia in 2005. After working as a research assistant for the Florida State University Coastal and Marine Laboratory, she began her M.S. in Biological Oceanography at the University of South Florida, where her research focused on the development of a viral marker of fecal pollution in coastal waters. Upon earning her M.S. in 2008, Erin served as a U.S. Peace Corps Volunteer in Guatemala. Erin returned to the University of South Florida as a Ph.D. student in the fall of 2011 to continue investigating viral markers of fecal pollution.

Synopsis

Wastewater pollution, containing excess nutrients and pathogens associated with human feces, negatively impacts economies and environmental and human health worldwide. Current bioindicators used to identify fecal pollution and public health risks fail to correlate and predict the presence of enteric pathogens. To improve the detection of fecal pollution in coastal environments, this research focuses on the development of the Pepper Mild Mottle Virus as a new bioindicator of fecal pollution.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Despite the widespread use of bacterial bioindicators of fecal pollution to monitor the sanitary condition of commercial molluscan shellfish, it has been well documented that they fail to correlate and predict the presence of enteric pathogens and risk of disease. Recent studies have demonstrated the potential of Pepper Mild Mottle Virus (PMMoV), an ornamental pepper virus present in feces, as a bioindicator of fecal pollution in coastal waters; however, no studies have investigated its use in commercial shellfish beds. As a result, the principal objective of this study is to further investigate the potential of PMMoV as a bioindicator of fecal contamination in commercial shellfish beds.

APPROACH

The first stage of this investigation will analyze the rate of bioaccumulation and retention of PMMoV in three species of molluscan shellfish (*Crassosstrea gigas*, *Ostrea edulis* and *Mytilus edulis*) through a series of mesocosm experiments. Additionally, the co-occurrence of PMMoV, norovirus and *Escherichia coli* will be analyzed in conjunction with the Netherlands Food and Consumer Product Safety Authority's Shellfish Surveillance Program throughout 2010, 2011 and 2012. Furthermore, the incorporation of PMMoV will be investigated in U.S. monitoring programs. The results of these studies will provide the information necessary to evaluate the use of PMMoV as a reliable bioindicator of fecal pollution in commercial shellfish beds.

EXPECTED RESULTS

The results of this study will indicate the usefulness of PMMoV as a bioindicator of fecal pollution in commercial shellfish beds. If the bioaccumulation and retention rates of PMMoV in shellfish correlate with that of known human enteric pathogens, then the utility of PMMoV as a bioindicator will be promising. Furthermore, if the presence of PMMoV correlates and co-occurs with the presence of human enteric pathogens in commercial shellfish beds in Europe and the United States, then this will further support the use of PMMoV as a reliable bioindicator of fecal pollution. The results of this work will help to assure the safety of human shellfish consumption worldwide.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Fecal pollution in aquatic systems is a growing problem worldwide and has devastating impacts on human and environmental health. Although many government agencies mandate the use of bacterial indictors to identify fecal pollution, it is well known that these indicators poorly correlate with risk of disease and contamination events. This research directly will address the need for an improved bioindicator. It also will have broader applications as a tool in the development of more efficient wastewater treatment methods.

Keywords: *fecal pollution, wastewater, Pepper Mild Mottle Virus, bioindicator, shellfish*

Water Quality: Coastal and Estuarine Processes
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Microbiology

Juan Fernando Villa-Romero

Microbial Phylogenetic Diversity and Rates of Selenium Oxidation/Reduction in Response to Increasing Salinities in Littoral Sediments of the Salton Sea, California

Bio

Juan Fernando Villa-Romero studied Biology at the Universidad Católica del Ecuador from 1999 through 2004. He then moved to the United States and received his undergraduate degree in Environmental Sciences from the University of Idaho, Moscow, in 2005 working on selenium contamination in southeast Idaho under the supervision of Dr. Susan Childers. Between that time and the beginning of his Ph.D. program in Microbiology, Juan Fernando worked with Dr. Matt Morra researching *Brassica*-based pesticides, and with Dr. John Coates studying microbial fuel cells. He also developed an after-school science program for underrepresented groups in Oakland, California, and travelled to the Ecuadorian Amazon as a consultant for Escuela Politécnica Nacional to evaluate the effects of oil development in the region. Currently, he studies the effect of environmental change on biodiversity and ecosystem functioning, focusing on salinity, microbial phylogeny and selenium biogeochemistry in the Salton Sea, under the supervision of Dr. Céline Pallud at the University of California, Berkeley.

Synopsis

This project focuses on littoral sediments of the Salton Sea and describes the effect of environmental change on microbial diversity and on the functioning of ecosystem processes relevant to the geochemical cycle of selenium. Flow-through reactors containing undisturbed sediment exposed to salinities that represent current and future scenarios for the lake will be used and evaluated using DNA microarrays. Results can describe future selenium behavior in the Salton Sea.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The Salton Sea is the largest inland body of water in California and is affected by elevated selenium concentrations in the sediments. Microbes control the geochemical cycle of selenium, which results in chemical species with different transport properties; salinity, on the other hand, is one of the factors controlling microbial diversity in the environment. In the next 15 years, the size of the Salton Sea is expected to shrink while water salinity increases. Consequently, submerged sediments would become gradually exposed to increasing salt concentrations and to atmospheric oxygen as the waterline of the lake recedes. The effect of these changes on microbial diversity has not been investigated for the Salton Sea, and neither their effect on the rates at which selenium is processed by indigenous microbial communities. This project focuses on littoral sediments of the Salton Sea and seeks to describe the effect of environmental change on biodiversity and on the functioning of ecosystem processes relevant to the geochemical cycle of selenium. More specifically, this study will investigate the phylogenetic diversity of microbial communities and the rates for selenium oxidation and reduction under a range of salinities that represent current and future scenarios for the Salton Sea. This study's specific research objectives are to: (1) evaluate the correlation between detected changes in microbial diversity and in selenium transformation rates to determine the contribution of biodiversity to selenium cycling in the Salton Sea; and (2) characterize across a vertical depth gradient relevant physical, biological and geochemical properties in undisturbed sediment samples collected from Salton Sea littoral sites with recorded low, medium and high selenium concentrations to determine the contribution of these properties to selenium cycling in the lake.

APPROACH

Sediment slurries and flow-through reactors containing undisturbed sediment samples will be used to measure rates for selenium oxidation and reduction. The use of undisturbed sediments provides much more relevant data because sediment characteristics are maintained; these characteristics are abolished in slurry incubations. Phylogenetic diversity will be measured by evaluating 16s rRNA clone libraries and DNA microarray data obtained from DNA isolated onsite and at the end of geochemical experiments.

EXPECTED RESULTS

Given the low concentrations of soluble selenium in Salton Sea water, neither specialized pathways, nor selenium-specific microbes are expected to dominate selenium processing in littoral sediments of the Salton Sea. Instead, it is hypothesized that denitrifiers drive the dissimilatory reduction of selenium oxyanions in the lake. For the salinities tested, an increase in denitrification rates is expected as salinity increases due to the availability of electron donors and to the energetic requirements associated with life at elevated salt concentrations. An increase in reduction rates for selenium also is expected as salinity increases given the hypothesized relationship between denitrifiers and the reduction of selenium oxyanions. Following an exposure to atmospheric oxygen, selenium oxidation rates are not expected to change as salinity increases. In terms of microbial diversity, initially abundant groups are expected to dominate as salinities increase while less abundant ones become more rare or undetectable. Microbial groups associated with denitrification are expected in anaerobic samples under all tested salinities. Members of the Haloanaerobiales order of Archaea are expected to dominate communities exposed to anoxia and the highest salinity level. Aerobic or anaerobic conditions are expected to result in significantly different microbial communities; however, under both conditions halophilic Bacteria and Archaea are expected to predominate.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Results from this investigation will provide restoration efforts targeting the recovery of the Salton Sea aquatic environment with information regarding the biogeochemical behavior of selenium under conditions expected to affect the lake in the near future. Today, elevated selenium concentrations in sediments of the Salton Sea represent a real threat to bird populations that include threatened and endangered species. In the 1980s, selenium was linked to mortality and developmental abnormalities in waterfowl in the Kesterson National Wildlife Refuge of the San Joaquin Valley in California. Furthermore, evaluating microbial diversity and specific geochemical reactions along a salinity gradient will contribute to the understanding of biodiversity, ecosystem functioning and their response to a changing environment.

Keywords: *Salton Sea, selenium, littoral sediments, salinity, microbial diversity, DNA microarrays, selenium geochemistry, oxidation/reduction rates, sediment slurries, flow-through reactors, biodiversity-ecosystem functioning (B-EF)*

Water Quality: Coastal and Estuarine Processes
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Microbiology

Yvonne Jia Jia Yuen

Development of Rapid Somatic and F+ Coliphages Detection Methods and Comparisons With Existing EPA Methods for Microbial Water Quality Monitoring and Contamination Source Tracking

Bio

Yvonne Yuen received her B.S. in Environmental Health from UW in 2005. She continued studying the health impacts of environmental risks at Emory University and received her M.P.H. in 2007. Following her M.P.H., she received a Public Health Fellowship from the Office of Water at EPA where she collaborated with other federal agencies and conducted a pilot epidemiological study examining the effects of water contamination on Native American communities. She began the Ph.D. program in Environmental Sciences and Engineering at University of North Carolina, Chapel Hill in 2009 and is conducting research in water microbiology.

Synopsis

Microbial water quality monitoring is critical for public health protection because studies have shown an increased risk of diarrheal diseases from swimming in contaminated water. However, most monitoring methods take 16 to 32 hours to obtain results, which is too slow for timely responses or public health warnings if water is contaminated. This project aims to develop new rapid methods that can detect possible water contamination as early as possible to ensure the safety of the consumers.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The objectives of this research are to develop rapid coliphage detection methods and improve current methods for water quality monitoring and contaminate source tracking. Rapid coliphage detection methods can assist recreational site operators in identifying possible fecal contamination early enough for timely responses of corrective actions or public health warnings. The validity of the developed rapid detection methods will be compared to the current standard EPA coliphage detection methods.

APPROACH

Two different approaches will be used to develop new and improved rapid coliphage detection methods: (1) the use of a liquid enrichment culture coupled with coliphage latex-agglutination test (CLAT) or real-time polymerase chain reaction (RT-PCR) assays, and (2) the direct plaque detection approach by improving the single agar layer (SAL) and direct membrane filtration methods to detect color changing or fluorescent signals from the developing plaques. The liquid enrichment and detection procedure involves the amplification of low concentrations of coliphages (as low as one PFU/L) during enrichment with *E. coli* hosts to levels that can be effectively detected by confirmation steps such as CLAT or RT-PCR. The improvement of the current SAL and direct membrane filter methods involve using fluorogenic or chromogenic additives in non agar-based media and identifying the combinations of optimal water sample volume, incubation conditions, *E. coli* host strain and membrane filter.

EXPECTED RESULTS

This research is expected to develop rapid, reliable, cost-effective and simple coliphage detection methods for water quality monitoring or contaminate source tracking. The new rapid methods should have a detection limit that would recognize possible viral contamination early enough for action without compromising the safety of the consumers. These methods should provide simple and direct ways to monitor water quality and are cost effective enough to be used routinely by recreational site operators. The validity of the developed methods will be compared with the current EPA 1601 and 1602 methods using both laboratory spiked samples and field samples. The results from this research also will produce a toolbox of analytical methods that enable users to choose the combinations of procedures that best match their purposes, training and resources by evaluating the critical components of coliphage detection methods.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Consuming fecally contaminated water can cause diarrheal diseases, which is the fifth leading cause of death in the world. The development of a reliable, simple and cost-effective rapid coliphage detection method can enable communities in low-income countries to test and monitor their drinking, irrigation and recreational water quality before use. The products from this research can also be used by many households in low-income communities or rural areas of the United States that are served by private ground water wells that are not regulated by the states and are not monitored for contamination.

Keywords: *water quality, coliphage, fecal contamination*

Hydrogeology and Surface Water

Water Quality: Hydrogeology and Surface Water
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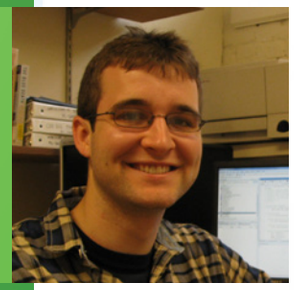
EPA Grant Number: FP917312
EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Engineering



Matthew Douglas Becker

A Comprehensive Modeling Approach for Predicting Nanoparticle Fate and Transport in Porous Media Under Varying Geochemical Conditions

Bio

Matthew Becker received his B.S. degree from the University of Missouri (MU) in May 2009. While at MU, he helped in completing a research project regarding the adaptation of landfill gas control strategies for landfills in Brazil. Since joining Tufts in 2009, he has focused his research on the fate and transport of contaminants in the subsurface environment. He particularly is interested in how geochemical conditions affect contaminant fate and transport in groundwater systems.

Synopsis

Despite possessing unique properties that make them beneficial for many applications, research has shown that engineered nanomaterials may be toxic. This project seeks to develop a modeling framework that relates the transport of nanoparticles in groundwater systems to transient geochemical conditions (e.g., salinity and pH), a determining factor in their mobility. This predictive capability will be important in assessing the risks that environmental releases have on groundwater resources.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Available laboratory data suggest that background solution chemistry conditions including, but not limited to, ionic strength and composition, solution pH, and presence of natural organic matter will strongly influence the deposition and re-entrainment behavior of nanoparticles in homogeneous and heterogeneous porous media. The goal of this project is to develop a tool that can effectively predict transport of common manufactured nanoparticles in the subsurface using inputs pertaining to characteristic features of the particles, porous media and background solution chemistry.

APPROACH

Using clean-bed colloid filtration theory as a basis, functional relationships will be developed that describe how nanoparticle attachment and detachment parameters change with variations in solution ionic strength, pH and presence of other aqueous constituents. The model will be calibrated using published data from transport experiments under various conditions and experimental data currently being produced in the Pennell laboratory at Tufts University. Through analysis of model sensitivity to changes in input parameters, governing parameters and mechanisms of transport and deposition can be further understood. Later, this model will be scaled up to more field-relevant scales and implemented in multiple dimensions to understand transport behavior and the potential pathway of exposure in more realistic scenarios.

EXPECTED RESULTS

This project will create a useful tool in assessing the contamination potential of groundwater resources due to releases of manufactured nanoparticles. Using the developed model's results as a guide for what may occur under ideal conditions, experimental results can be further explored to understand the influence that complex background solution chemistry characteristics have on particle deposition. The inherent value of coupling model development and calibration with experimental data is the ability to relate laboratory results to the prediction of potential contamination scenarios for nanoparticle release at the field scale. This research also will provide another tool upon which scientists and policy makers can consult in decisions regarding regulation of nanoparticles and other similar emerging contaminants.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Currently, regulations controlling nanoparticle release into the environment virtually are nonexistent. To implement such policies, understanding of the fundamental mechanisms of nanoparticle behavior in environmentally relevant solution chemistries must be built upon. Through more informed modeling of nanoparticle fate and transport, the scientific community will be better able to relate existing and future toxicity studies' results to the potential environmental and public health threats that these materials might pose.

Keywords: *nanoparticles, mathematical modeling, solution chemistry, groundwater quality, aquifer, geochemistry*

Water Quality: Hydrogeology and Surface Water
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EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Michael F. Chislock

Ecological Consequences of Herbivore Adaptation to Toxic Cyanobacteria: Implications for the Control of Freshwater Harmful Algal Blooms

Bio

Michael Chislock received a B.S. in Ecology from Clarion University in 2008 and will receive his M.S. in Fisheries from Auburn University in the summer of 2011. Michael will begin a Ph.D. in Fisheries at Auburn in the fall of 2011. His undergraduate research in Dr. Andy Turner's laboratory examined the negative effects of eutrophication on perception of predators by freshwater snails. His current research in Dr. Alan Wilson's laboratory focuses on cyanobacterial toxins as chemical defenses against *Daphnia* herbivores in freshwater lakes.

Synopsis

Blooms of toxic cyanobacteria threaten aquatic communities and global water supplies. Cyanobacterial toxins have been implicated in the poisoning of drinking water supplies, food webs, pets and humans. Cyanobacteria also are responsible for several off-flavor compounds found in drinking water and aquaculture-raised fish. This project will examine the role of adaptation by a generalist herbivore to cyanobacteria, for mitigating and restoring freshwater ecosystems affected by nutrient enrichment.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Toxin-producing cyanobacteria have frequently been hypothesized to limit the ability of herbivorous zooplankton (such as *Daphnia*) to control phytoplankton biomass by inhibiting *Daphnia* feeding, population growth, and in extreme cases, causing *Daphnia* mortality. However, recent research has shown that populations of the generalist herbivore, *Daphnia*, can evolve to tolerate cyanobacteria and their associated toxins following prolonged exposure to cyanobacterial blooms. The objectives of the proposed research are to understand the ecological consequences of *Daphnia* adaptation to toxic cyanobacteria and to determine the implications of herbivore evolution for the control of harmful algal blooms in nature.

APPROACH

This research will use *Daphnia* as a model organism for studying the role of herbivore adaptation in food webs. *Daphnia* and cyanobacteria provide an ideal system to examine the consequences of herbivore adaptation as *Daphnia* are keystone herbivores in the pelagic zone of lakes and cyanobacteria can have negative effects on community structure and function. As *Daphnia* can evolve to tolerate toxic cyanobacteria, the response of eutrophic ecosystems to abatement efforts may depend on the role of *Daphnia* adaptation to cyanobacteria. This study will test this hypothesis using a combination of laboratory feeding assays, limnocorral experiments and whole pond experiments.

EXPECTED RESULTS

The presence of *Daphnia* seems to be critically important to the success of biomanipulation efforts and understanding the causes and consequences of intraspecific variation within *Daphnia*, for traits conferring tolerance to toxic cyanobacteria may aid in the future management of eutrophic lakes. It is anticipated that the results of this research will add to a growing body of literature emphasizing the importance of variation within species for community dynamics and ecosystem function. Furthermore, management of *Daphnia* populations tolerant of toxic cyanobacteria may provide a sustainable alternative for the control of freshwater harmful algal blooms. The results of this work will be directly applicable to the control of toxic cyanobacterial blooms in aquaculture ponds and in municipal drinking water systems.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

This research will have significant impacts on science and society by: (1) advancing knowledge of the role of keystone herbivore adaptations in controlling harmful algal blooms, (2) improving management of harmful algal blooms through biomanipulation, (3) teaching outreach courses to diverse audiences, and (4) mentoring high school and undergraduate students. Cyanobacterial toxins have been implicated in the poisoning of drinking water supplies, food webs, pets and humans. Despite dramatic improvements in water quality since the enactments of the Clean Water and Safe Drinking Water Acts in the 1970s, eutrophication and cyanobacterial blooms are still prevalent in surface waters across the United States. This research aimed at the improved management of toxic cyanobacterial blooms has potential benefits to society with respect to water quality, livestock production, aquaculture and human health.

Keywords: *intraspecific variation, eutrophication, biomanipulation, harmful algal blooms, toxins, toxic cyanobacteria, herbivore, adaptation,* Daphnia, *aquaculture*

Water Quality: Hydrogeology and Surface Water
Northwestern University (IL)
EPA Grant Number: FP917290
EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2014
Project Amount: $126,000
Environmental Discipline: Hydrology

Jennifer Debra Drummond

Reducing Human Health Risks From Waterborne Diseases

Bio

Jennifer Drummond received her undergraduate degree in Chemical Engineering from the University of Illinois at Urbana-Champaign in 2004. After 4 years of working as a technical transfer scientist for Johnson and Johnson, she entered the Ph.D. program in Chemical Engineering at Northwestern University. Her research focuses on modeling water contamination and waterborne disease transmission in rivers. She currently is investigating the effects of flow variations on pathogen transport in rivers.

Synopsis

Waterborne diseases are a significant concern and a prevalent health issue. It is difficult to predict the migration of pathogens, as rivers provide a means of rapid and long-distance transmission of these organisms. This project analyzes the transport paths of pathogens in rivers to predict pathogen migration downstream. It will help reduce human health risks by predicting the fate of pathogens upon entering a stream and supporting development of improved management practices.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The overall objective of this research project is to improve understanding of the transport of pathogenic organisms in rivers, principally focusing on the deposition and resuspension mechanisms that control pathogen residence times. Knowledge gained will be codified in a model to predict the fate of pathogens in streams. This model will improve management strategies for reducing the human health risks from waterborne diseases.

APPROACH

The research plan consists of laboratory, field and computational work on pathogen transport. An integrated modeling framework will be developed for pathogen dynamics in rivers. The model will account for a range of residence times within or near the streambed, including deposition and resuspension events. Laboratory experiments will be conducted to evaluate processes that are hypothesized to control pathogen deposition and resuspension, and field experiments will be conducted to evaluate and assess the applicability of the modeling framework in predicting the migration of pathogens in small rivers.

EXPECTED RESULTS

An advanced model that can predict how pathogenic organisms will impact downstream environments will improve management of waterborne disease transmission. By combining laboratory and field experiments with modeling, observed pathogen transport can be directly incorporated into the model. The model will provide an improved tool for evaluating risks of waterborne disease transmission under natural flow variations and modified flow regimes associated with either climate change or stream regulation/restoration. This tool then can be used to design improved management practices for reducing downstream transport of pathogens particularly with stream flow variations and flood events.

POTENTIAL TO FURTHER ENVIRONMENTAL/HUMAN HEALTH PROTECTION

Pathogens enter small streams in a variety of ways, notably including shallow groundwater discharge, overland flow and direct inputs from animals. This project will improve assessment of the transport of pathogenic organisms in rivers, thereby facilitating evaluation of the risks of waterborne disease transmission. It will help to reduce human health risks by supporting the development of improved management practices for reducing waterborne disease transmission.

Keywords: *waterborne diseases, pathogen, pathogenic organisms, contaminant transport, modeling, rivers*

Water Quality: Hydrogeology and Surface Water
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Environmental Toxicology

Derek Michael Heeren

Phosphorus Leaching in Riparian Floodplains: Preferential Flow and Scale Effects

Bio

Derek Heeren received an undergraduate degree in 2004 and an M.S. degree in 2008 in Agricultural and Biosystems Engineering from South Dakota State University in Brookings, South Dakota. Between these two degrees, he spent 2 years working as a laboratory supervisor in a geotechnical soil testing laboratory at SCI Engineering, Inc., in St. Charles, Missouri. He currently is a Research Engineer in Biosystems and Agricultural Engineering at Oklahoma State University, where he assists in research projects on streambank stability, alluvial depletion and subsurface nutrient transport.

Synopsis

It often is assumed that phosphorus is transported primarily through surface runoff, but subsurface phosphorus transport also may be significant in gravelly floodplains. Phosphorus leaching from the soil surface to the alluvial aquifer will be measured at the point scale in the laboratory and three plot scales with field infiltration experiments in the Ozark Ecoregion. It is expected that results will have wide-reaching implications for how gravelly floodplains throughout the world are managed.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Information is needed on the potential significance of connectivity between phosphorus in surface runoff and groundwater and phosphorus movement from the soil to groundwater in watersheds with cherty and gravelly soils. The potential for phosphorus leaching commonly is estimated based on point-measurements of soil test phosphorus (STP) or measurements of the sorption capability of disturbed soil samples representing the soil matrix. However, in these areas, gravel outcrops and macropores (visibly observed in previous research activities) occur on the floodplains and lead to extremely high infiltration rates. This research project will investigate how macropores and gravel outcrops in alluvial floodplains create a scale-dependent impact on contaminant leaching through soils through innovative field studies by: (1) quantifying the spatially variable phosphorus transport capacity of heterogeneous, gravel soils, and (2) evaluating the influence of experimental scale on observed phosphorus leaching.

APPROACH

The subsurface heterogeneity in the alluvial deposits at three riparian floodplain sites in Oklahoma and Arkansas first will be investigated using electrical resistivity imaging techniques by producing a three-dimensional map of the alluvial floodplain subsurface at each proposed field site. This three-dimensional image will allow the determination of areas of localized gravel outcrops that may lead to increased leaching potential. Phosphorus leaching will be measured at the point scale in the laboratory using flow cell experiments of disturbed soil samples and at plot scales (approximately 1, 10 and 100 square meters) with replicated infiltration experiments at the three riparian floodplain sites. The injection tests in the field will be imaged using innovative electrical resistivity techniques. Through numerical modeling, the research will be extended beyond the three specific floodplain sites by estimating the phosphorus concentration and load entering gravel subsoils for various topsoil depths, storm sizes and initial phosphorus concentrations for the Ozark Ecoregion.

EXPECTED RESULTS

It is expected that measured leaching will generally increase as the scale increases from point to plot scales. Leaching potential should not be quantified based on disturbed, small-scale samples of floodplain sediment. This research has wide-reaching implications for how riparian floodplains throughout the world are managed. Future management recommendations for gravelly riparian floodplains may be altered as a result of these research findings.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Billions of dollars are spent annually through governmental programs in North America and Europe to mitigate surface runoff, sediment, pesticide and nutrient loads through conservation and restoration of riparian buffers. Although these management plans can be effective, this research hypothesizes that leaching and subsurface phosphorus transport also could be a contributing factor in certain conditions with this transport occurring along focused as opposed to diffuse pathways. Broad-reaching implications extend beyond phosphorus; this research will affect the use of riparian buffers for mitigating other contaminants such as nitrogen, pathogens and pesticides to stream systems.

Keywords: *alluvial floodplains, geophysical mapping, leaching, phosphorus, preferential flow, scale*

Water Quality: Hydrogeology and Surface Water
University of Arkansas (AR)
E-mail: kknierim@uark.edu
EPA Grant Number: FP917347
EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Katherine J. Knierim

Using Stable Isotopes to Quantify Sources of Water and Characterize Nutrient Fluxes in an Ozark Cave Stream, Arkansas

Bio

Katherine Knierim received her B.S. in Geology at Bowling Green State University in 2007 and her M.S. in Geology at the University of Arkansas in 2009. Katherine is currently a Ph.D. candidate in the Environmental Dynamics Program at the University of Arkansas and is using stable isotopes to research the geochemistry of caves. She wants to better understand how contaminants are transported and attenuated in karst systems so water quality in caves and springs can be better protected.

Synopsis

Karst landscapes are characterized by rapid transport of surface water into the subsurface because of fractures, dissolution-enlarged conduits, sinkholes and sinking streams, for example. To better understand how contaminants enter the subsurface in karst systems, this project will explore sources of water in a cave stream and relate those water sources to the movement of contaminants – including nutrients, bacteria and sediment – which can negatively impact cave and spring water quality.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research aims to quantify water sources in a cave stream during base flow and storm events using stable isotopes to better assess how contaminants – including nutrients, bacteria and sediment – impact cave and spring water quality. Much research has focused on water quality at springs, but sampling within a cave conduit provides access to groundwater in equilibrium with gaseous voids and the ability to directly sample bedrock matrix waters. Quantifying the correlation between water sources and water quality in caves will identify the source areas and mechanisms of contaminant transport through heterogeneous karst systems, which is important for developing management strategies to protect karst aquifers from contamination.

APPROACH

Isotopic hydrograph separation techniques will be used to quantify source water contributions in a cave stream and relate these water sources to water quality. A three-component hydrograph separation will be completed using stable isotope ratios of water (δD and $\delta^{18}O$) and the concentration and isotopic composition of dissolved inorganic carbon ($\delta^{13}C$) to quantify proportions of precipitation, soil and bedrock matrix water in a cave stream during storm events. The detailed hydrologic budget for recharge developed by quantifying water sources in the cave stream allows contaminant flux to be related to the proportions of diffuse (soil and bedrock matrix water) versus quick flow (precipitation). Additionally, dissolved organic carbon and nitrogen species will be analyzed for isotopic composition to better assess carbon and nitrogen sources and biogeochemical cycling along groundwater flow paths. Seasonal influences will be addressed by monitoring storms following wet and dry antecedent conditions during the spring and fall, respectively.

EXPECTED RESULTS

Developing a hydrologic budget using isotopic hydrograph separation techniques will quantify groundwater versus surface water sources to karst springs and highlight variability within and between storm events. Hydrograph separation techniques in karst settings have focused on storm-flow hydrographs from springs, but the geochemistry of spring waters that have encountered air-filled voids may be different than those moving through saturated conduits and fractures. Therefore, this research will explore the interaction of the cave stream with the cave atmosphere—a potentially important control on water geochemistry because of seasonal variations in carbon dioxide concentration in the cave atmosphere. Source water contribution (diffuse versus quick flow) and the partitioning of contaminants between dissolved and particulate phases are expected to control the flux of contaminants during storm events.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

In many cave and spring systems, an inability to identify sources of contaminants continues to hinder the development of best management practices for reducing non-point source pollution. Water quality impacts in northwestern Arkansas due to suburban and urban development and agriculture will be addressed to characterize contaminant transport along sensitive cave flow paths. These research findings will have broad application to karst systems around the world, which is of particular importance because karst aquifers are a global water resource and are experiencing increasing stress due to population growth in karst regions.

Keywords: *caves, karst, water quality, stable isotopes, hydrographs*

Water Quality: Hydrogeology and Surface Water
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Agricultural Engineering

Katrina Martta Koski

Hyporheic Zone Exchange in Phreatic Karst Conduits With Contaminant Implications

Bio

Katrina Koski earned a B.S. in Physics from Lake Forest College. She received an M.S. in Physics from New Mexico Tech for work involving galactic dynamics. After 5 years working for a government contractor, she returned to school in the Earth Sciences. Katrina currently is enrolled in a Hydrology Ph.D. program at New Mexico Tech where her research is on karst hydrology.

Synopsis

An important interaction at the margin of streams is hyporheic flow, where water leaves the stream, travels in the porous media at the bottom of the stream, and returns to the stream. Unique to karst aquifers are conduits, water-filled caves analogous to streams. This project seeks to test the hypothesis that hyporheic flow occurs in the sediments and porous limestone rock at the margin of karst conduits. The exchange may have an important role in contaminant storage and transformation in karst.

OBJECTIVE(S)/RESEARCH QUESTION(S)

This research seeks to confirm the presence of karst conduit hyporheic flow and to understand its role in the migration, sequestration and transformation of natural and anthropogenic chemical constituents in water.

APPROACH

This project will use modeling and field observations to verify the existence of karst conduit hyporheic flow and their role in the transporting and processing of contaminants. Initial modeling will consist of simple analytical and numerical models at the beginning of the project to inform the design of the observational program. A field project using traditional methods from surface water hyporheic studies, and karst studies, such as dye traces, will verify hyporheic flow at the field site: Wakulla Leon Sinks Cave in Florida. The project will end with modeling as a descriptive tool, with computational fluid dynamics models run on multicore desktops and super computers.

EXPECTED RESULTS

The models and field experiment will verify the existence of karst conduit hyporheic flow and lead to characterization of its properties, forcing and spatial and temporal scales. Finally, the project will examine how well karst hyporheic flow facilitates sequestration and transformation of contaminants.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The ultimate result of the project will be to produce a set of results, conceptual models and tools that can help scientists and policy makers anticipate the impacts of floods, droughts and contamination events on water quality, and the consequences for water supply management and water quality monitoring decisions.

Keywords: *karst hydrology, karst aquifer, hyporheic, water quality, groundwater*

Water Quality: Hydrogeology and Surface Water
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EPA Project Officer: Brandon Jones
Project Period: 8/1/2011 - 7/31/2014
Project Amount: $126,000
Environmental Discipline: Hydrology

Kristin M. Mikkelson

Impacts of the Mountain Pine Beetle on Water Quantity and Quality in the Rocky Mountain West

Bio

Kristin Mikkelson received her undergraduate degree in Environmental Engineering from Cornell University in 2008. The following summer she worked for Outward Bound, an organization dedicated to leadership and self-discovery through wilderness expeditions. After working for Outward Bound, she began her doctoral studies at the Colorado School of Mines in Hydrological Engineering. Her research focuses on the impacts the mountain pine beetle epidemic may have on water quality and quantity in the Rocky Mountain West.

Synopsis

The mountain pine beetle (MPB) epidemic in western North America has generated growing concern in recent years. Increasing numbers of outbreaks have affected an estimated 2 million acres of forest in Colorado and Wyoming alone, during 2008. It has been hypothesized that the effects of the MPB outbreak will be similar to those observed after forest harvesting. High tree mortality rates of recent MPB infestations have the potential to induce significant changes in the forest canopy. Parflow, a variably saturated groundwater flow model, was coupled with the Common Land Model (CLM) to incorporate physical processes related to energy at the land surface and used to investigate the changing hydrologic and energy regime associated with MPB infestations. Our results demonstrate that MPB-infested watersheds will experience a decrease in evapotranspiration and an increase in snow accumulation accompanied by earlier and faster snowmelt. Impacts are similar to those projected under climate change, yet with a systematically higher snowpack. These results have implications for water resource management due to higher tendencies for flooding in the spring and drought in the summer.

OBJECTIVE(S)/RESEARCH QUESTION(S)

The mountain pine beetle (MPB) epidemic has recently reached epidemic proportions and could have a drastic impact on water quality and quantity. Forest canopy changes have the potential to alter multiple components of the local water and energy cycles along with forest biogeochemistry. The objective of this research is to study the changing hydrologic regime due to the MPB, along with investigating the altered transport of metals and organic carbon within the impacted watershed.

APPROACH

To investigate the changing hydrologic and energy regimes associated with the MPB epidemic, a suite of methods will be used such as field studies, laboratory experiments and numerical modeling. Field studies will be used to gather data on the altered metal and dissolved organic carbon flux, along with evapotranspiration and snow depth measurements. Laboratory studies will investigate the possible metal release associated with soils in MPB affected catchments. Numerical modeling will be used to research the changing hydrology, biogeochemistry and energy fluxes associated with the MPB epidemic and will be compared to field studies.

EXPECTED RESULTS

As climate change has the potential to drastically impact water quantity, this research aims to determine the magnitude of impact the MPB infestations may have on water quantity, specifically the timing of runoff and base flows under different climate scenarios. Field studies and modeling will give water managers in the Rocky Mountain West a better understanding of how their water supplies might be altered. This research also will determine whether or not water treatment facilities have to be concerned with an increased flux of metals and dissolved organic carbon, or if there are underlying mechanisms in MPB impacted watersheds mitigating the release of potential contaminants.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

Anthropogenic climate change has magnified the current MPB infestation in the Rockies; specifically, consecutive mild winters have not sufficiently suppressed MPB populations and beetles now thrive at higher elevations. This research is imperative due to the Rocky Mountains being a source-water region for much of the American West along with the region's sensitive alpine ecology. In the end, the MPB epidemic could lead to drinking water, fishery and economic concerns through perturbations to both water quality and quantity.

Keywords: *mountain pine beetle, hydrology, biogeochemistry, metal flux, dissolved organic carbon, water quantity, water quality*

Water Quality: Hydrogeology and Surface Water
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EPA Grant Number: FP917375
EPA Project Officer: Brandon Jones
Project Period: 9/1/2011 - 8/31/2013
Project Amount: $84,000
Environmental Discipline: Environmental and Water Science

Jesse D. Robinson

Components of Riverbed Filtration Enhancement in Urban Stream Restoration Sites

W

Bio

Jesse Robinson received his undergraduate degree in Environmental Science from Indiana University with high distinction. His research was supported by the Hutton Honors College. Following graduation, he worked for the Kentucky Department of Environmental Protection reviewing physical impacts to streams and wetlands, including restoration. His graduate research focuses on assessing the functional improvement resulting from stream restoration. He is active in environmental education and outreach.

Synopsis

Urban streams are likely to receive polluted runoff from our built environment and may suffer from serious historic pollution and modification. Despite this, stream restoration projects often are not located in these areas because of difficulty in assuring improvement to aquatic resources. This research will examine urban restoration sites to determine if there is evidence of an important natural function: the mixing of surface and groundwater, which can influence nutrient processing.

OBJECTIVE(S)/RESEARCH QUESTION(S)

Due to the extensive and serious nature of impairment in many urban streams, successful aquatic restoration projects remain a challenge. However, physical alterations to streams resulting from restoration activities may be capable of enhancing hydraulic drivers of riverbed filtration, potentially improving important stream functions. This study will explore relationships between transient storage modeling and stream channel characteristics to identify trends in hyporheic exchange, a driver of riverbed filtration, through examining urban and non-urban degraded, reference condition and restored sites.

APPROACH

Demonstration of improved stream function is important for determining successful aquatic restoration. Direct measurement of these functions, such as nutrient processing, often is complicated by data intensive methods, site heterogeneity and temporal variations in environmental factors. Transient storage modeling (TSM) may represent one method for achieving rapid assessment of indicators of improved stream function. TSM utilizes a mass balance approach to following a conservative tracer into sub-surface storage zones within streams, and can provide information about exchange rates and the residence time of water moving through these zones. TSM measurements provide information about the physical drivers of exchange and the characteristics of the streambed, which are known to relate to other important stream functions.

EXPECTED RESULTS

Transient storage modeling has been used in a variety of landscapes, and is under exploration in a network of degraded, reference condition and restored sites. Post-processing analysis of the conservative tracer signal provides information about sub-surface storage zones, but other processes, such as surface detention areas, must be carefully isolated. Appropriate characterization of stream parameters at each site is crucial to developing scaling relationships between model output and drivers of exchange. Despite complexities, physical enhancement through use of structures in restoration sites has been proven to alter hydraulic drivers of riverbed filtration. Due to these enhancements, differentiation between the transient storage signal in degraded, reference condition and restored sites is anticipated. The degree of differentiation in this signal, and predictive power of direct measurements of stream characteristics, will provide evidence for the success of both the methods proposed and urban stream restoration in general.

POTENTIAL TO FURTHER ENVIRONMENTAL/ HUMAN HEALTH PROTECTION

The impairment seen in urban streams reduces the ability of these ecosystems to provide important functions, from support of aquatic life at the base of the food chain, to the removal of pollutants from surface waters. This state of impairment also has the effect of reducing recreational and quality of life benefits in areas where people are most likely to live. For citizens in these areas, developing strategies to repair these ecosystems requires that they begin with a complete understanding of the state of efforts in urban environments to date.

Keywords: *water quality, stream restoration, urban, riverbed filtration, Clean Water Act*

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