ANNUAL REPORT 2013-2014

TYSON RESEARCH CENTER

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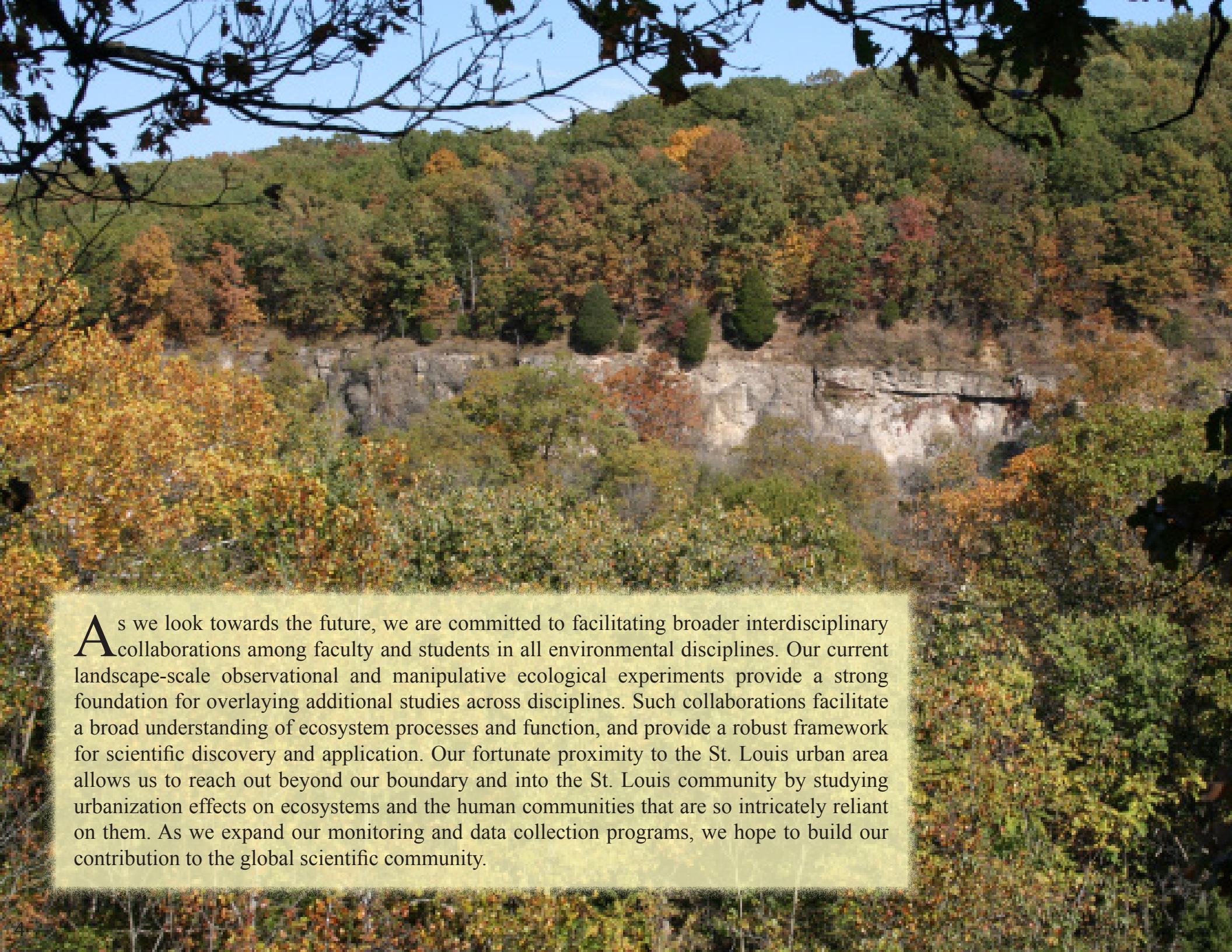
Saddleback caterpillars, Acharia stimulea

Tyson Research Center: over 50 years in the field

Tyson Research Center has a rich and varied history since the site was acquired by Washington University in St. Louis in 1963. In the early years, it was a secluded site for natural history enthusiasts to explore the rolling hills of oak-history forest and to spot birds on nature walks. As researchers began using Tyson, the focus was on natural history and resource management; the first research publication from work performed on site reported management practices for a local herd of elk. Since then, many faculty, students, and staff from Washington University have utilized Tyson for a variety of studies, and have honed in on taxa from microbiota to amphibians and forests. As usage of Tyson grew, so did its outreach into the community through the Tyson Field Science Program. This long-running program provided St. Louis youth from the suburbs to the inner city an opportunity to experience and understand nature.

In recent years, Tyson's mission has evolved: we are currently a site for environmental research and education for faculty, students, and staff from Washington University and other institutions in the region, the country, and around the world. As a research center, our primary goal is to facilitate high-quality research in environmental disciplines. Currently, the bulk of the research at Tyson is ecological, but we are expanding our focus by incorporating educational research into the fold. As a result, our educational programming is deeply integrated into our research mission, where undergraduate students and high school youth work elbow-to-elbow with professional researchers from technicians to tenured faculty. This integrated approach benefits faculty research programs by supporting the high level of productivity required to conduct intense summer field research, and provides life-changing authentic research experiences for students. In addition to Tyson-based programs, Washington University and other area institutions use the site for coursework.

Eastern grey treefrog, Hyla versicolor



As we look towards the future, we are committed to facilitating broader interdisciplinary collaborations among faculty and students in all environmental disciplines. Our current landscape-scale observational and manipulative ecological experiments provide a strong foundation for overlaying additional studies across disciplines. Such collaborations facilitate a broad understanding of ecosystem processes and function, and provide a robust framework for scientific discovery and application. Our fortunate proximity to the St. Louis urban area allows us to reach out beyond our boundary and into the St. Louis community by studying urbanization effects on ecosystems and the human communities that are so intricately reliant on them. As we expand our monitoring and data collection programs, we hope to build our contribution to the global scientific community.

Far left: limestone bluff at Tyson; left: students on winter class visit; above: American bellflower, *Campanulastrum americanum*; below: prickly pear cactus, *Opuntan compressa*, in bloom.

Photo: Jonathan Myers

Tyson Executive Committee

Washington University leadership providing high-level guidance on strategy and planning

Kim Medley, Interim Director, Tyson Research Center
Holden Thorp, Provost & Executive Vice Chancellor for Academic Affairs
Henry S. Webber, Executive Vice Chancellor for Administration & Professor of Practice, Sam Fox School & Brown School
Barbara Schaal, Dean, Faculty of Arts & Sciences & Mary-Dell Chilton Distinguished Professor, Department of Biology

Tyson Advisory Committee

Washington University faculty and staff providing guidance and advice on management challenges and policy

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Rod Barnett, Professor & Chair, Master of Landscape Architecture Program
David Fike, Associate Professor, Department of Earth and Planetary Sciences & Director, Environmental Studies
Susan Flowers, Education & Outreach Coordinator, Tyson Research Center
Dan Giammar, Walter E. Browne Professor of Environmental Engineering, Department of Energy, Environment, and Chemical Engineering
Pete Jamerson, Facilities Manager, Tyson Research Center
Andrew Johnstone, Business Manager, Department of Biology
Tiffany Knight, Associate Professor, Department of Biology
Scott Mangan, Assistant Professor, Department of Biology
Kathy Miller, Professor and Chair, Department of Biology
Jonathan Myers, Assistant Professor, Department of Biology
Brent Williams, Raymond R. Tucker Distinguished I-CARES Career Development Assistant Professor, Department of Energy, Environmental, and Chemical Engineering

Witch hazel, Hamamelis virginiana

TYSON RESEARCH CENTER

Tyson Staff

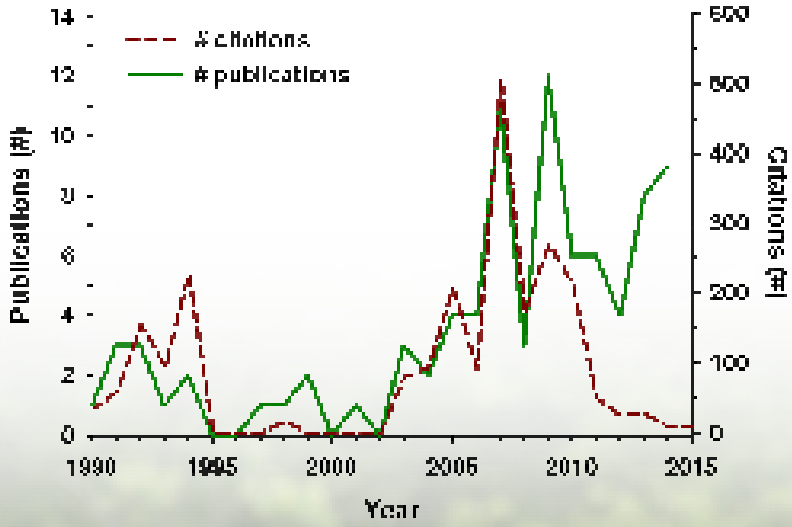
Kim Medley, PhD, Interim Director
Elizabeth Biro, MS, Field Station Ecologist & Lab Manager
Ruth Ann Bizoff, Administrative Coordinator
Tim Derton, Maintenance Technician
Susan Flowers, MA, Education & Outreach Coordinator
Pete Jamerson, Facilities Manager
Andrew Johnstone, Business Manager
Travis Mohrman, Naturalist & Garden Manager
Nancy Schulte, Administrative Assistant
Marko Spasojevic, PhD, Post-doctoral Associate (Myers Lab)
Claudia Stein, PhD, Tyson Research Scientist (Mangan Lab)

RESEARCH & MONITORING

Research Summary

As a formal research center, our primary objective is to facilitate environmental research for faculty, students, and staff from Washington University and other institutions. Research at Tyson has grown substantially over the past 50 years, as revealed in a doubling of the rate of publications generated from Tyson-based research (see page 39). During 2013-2014, investigators from seven Washington University departments and eleven institutions conducted research on more than 35 research projects, with at least 18 additional independent undergraduate and pre-college student projects. Three undergraduate fellows first-authored manuscripts that were published during this reporting cycle.

While many field stations double as biological preserves, Tyson has a history of land use that has resulted in a non-pristine site. This has provided a wealth of research opportunities in restoration and invasion ecology, and has allowed for landscape-level experimental manipulations. The glade restoration experiment, led by principal investigator Dr. Tiffany Knight, cut 32 glades of three sizes and two shapes into the forest at Tyson and adjacent private properties. Her work set out to disentangle the mechanisms that explain why the species-area relationship changes with habitat size. Such research questions have important implications for understanding declines in species richness with habitat loss, and inform strategies for restoration.



The longest-running research project at Tyson is the Forest Dynamics Plot. In 1981, Dr. Victoria Sork and graduate student Carol Hampe surveyed trees in a 4 hectare forest plot at Tyson, and fortuitously collected data using the same methods that were in use in a similar plot in Barro Colorado Island, Panama. Dr. Jonathan Myers and his research team expanded the plot to 25 hectares in 2011, where they have completed an intensive survey of over 39,000 trees and more than 30 species. The plot was incorporated into the Smithsonian ForestGEO (Forest Global Earth Observatory) network in 2013, and has contributed to the first network-wide analysis of data generated from the 61 member sites. Observational studies replicated at a global scale have the capability of revealing answers to questions about global climate change, drought, and broad-scale factors influencing all of humanity.

Many long-term projects are in their early stages, such as research examining the interactive effect of phylogenetic similarity among plant species on plant-soil feedbacks driving plant community composition. Investigators are examining cutting-edge questions in disease ecology, landscape genetics/genomics, and biogeography. Tyson is also adding research infrastructure to contribute to regional and global databases, and to contribute to the global field station community. Finally, we foster a collaborative environment at Tyson in order to reveal opportunities for interdisciplinary research in a wide range of environmental disciplines.

Photo: Jonathan Myers

Lauren Woods, PhD 2014

The influence of metacommunity size on the scaling of species diversity

Natural disturbances play an important role in altering and maintaining patterns of species richness. However, the frequency and intensity of natural disturbances such as heat waves, floods, and droughts are expected to increase with climate change. These changes in natural disturbance regimes are likely to lead to species loss across ecosystems, making it crucial to understand how natural disturbances affect species richness, and what processes are essential for the recovery and maintenance of species richness.

As a part of my dissertation research at the Tyson Research Center, I used experimental aquatic plant communities to investigate the effect of an extreme heat and drought event on species richness, and the importance of dispersal for the recovery of species richness following this disturbance. Initially I had set up the experimental communities to investigate the effect of an herbicide disturbance on aquatic plants, but the summer of 2012 was the most severe summertime drought the Central Great Plains had experienced in 117 years, and it had drastic effects on the aquatic plant communities.

Following this extreme heat and drought event, there was a significant loss in aquatic plant species richness, as well a loss of some species from the entire experiment. Species composition was also affected, with aquatic plant communities becoming more similar to one another after the drought. Experimental communities were then placed in either a control or in one of three dispersal treatments to determine the importance of dispersal for the recovery of species richness. I found that regardless of dispersal treatment, there was an increase in aquatic plant species richness following dispersal, suggesting that even *low amounts of species dispersal can facilitate the recovery of species richness in aquatic plant communities*.

Dr. Woods is currently a post-doctoral fellow at Davidson College.

Kristin Powell, PhD 2013

The effect of invasive species on abundance distributions

Invasive plants are noxious weeds that become dominant members of a plant community and can blanket large swaths of land. Despite this, the impacts of invasive plants on native biodiversity remain controversial. Some studies show large declines in native biodiversity in plant-invaded habitats, whereas others have noted that plant invasions rarely, if ever, cause extinctions of native species. For my dissertation, I studied this seemingly conflicting literature. I hypothesized that the effect of invasive plants on biodiversity is scale-dependent—in other words, it can be explained by a difference in the size of the habitat area investigated in each study.

I surveyed plant communities of increasing area in habitats with and without invasive plants. I conducted these plant surveys in three disparate ecosystems—a temperate forest at Tyson Research Center, sub-tropical forest in Florida, and tropical forest in Hawai'i, USA. In all three ecosystems, *invasive plant species caused large declines in biodiversity in small habitat areas. However, this negative effect of invasive plants on biodiversity disappeared as the size of the sampled habitat area increased.*

Results showed that this scale-dependent loss in native biodiversity was in part due to larger declines in the abundance of common species compared to the abundance of rare species. To further explore this, I studied the invasive plant *Lonicera maackii* (Caprifoliaceae). *L. maackii* is also known as bush honeysuckle and is a shrubby, forest invader in the Midwest. At Tyson, I explored bush honeysuckle's effects on four

common and four rare native plant species. I tagged individual plants of every species and tracked their growth, survival, and seed production through time. *The overall population growth of the common plants was consistently more negatively affected than that of the rare plants.* This was due to larger declines in common species' seed production and greater sensitivity of their population growth to declines in the number of reproductive plants in a population.

I also tested if the effects of bush honeysuckle on common and rare plants were due to changes it causes in environmental conditions after it invades a forest. The results of these experiments showed that *bush honeysuckle significantly reduces light levels that reach the forest floor and that rare plants that live in the forest understory tend to be more shade-tolerant than common plants.*

My research provided a framework for how to understand biodiversity loss from plant invasions and predict future extinctions in the context of species commonness and rarity, and reconciled the differences observed among local and broad-scale effects of invasive plant species on biodiversity.

Dr. Powell is now a program manager at the Smithsonian Tropical Research Institute.

Forest Dynamics Plot

Jonathan Myers, Assistant Professor

Washington University, Department of Biology

In 2014, the Tyson Forest Dynamics Plot celebrated its first anniversary as a member of the Smithsonian Institution's Forest Global Earth Observatory (ForestGEO): the largest, systematically studied network of forest ecology plots in the world. ForestGEO comprises a total of 61 research plots in 24 countries that collectively monitor ~6 million trees and ~10,000 plant species. The Tyson plot complements other ForestGEO plots in three important ways. First, the Tyson Plot is the first ForestGEO plot located in the Ozark Ecoregion of the United States, a biologically diverse but relatively understudied region of high conservation significance. Second, the first section of the Tyson Plot was established ~35 years ago at the same time that the first ForestGEO plot was established in a high-diversity tropical rainforest at Barro Colorado Island, Panama. Over the last three decades, researchers from the University of Missouri-St. Louis and Washington University have measured the growth, mortality, and species composition of all trees and shrubs greater than 1–2 cm in diameter, resulting in a long-term record of forest change that will facilitate comparative studies of diversity and dynamics across temperate and tropical forests. Third, the plot history provides unique opportunities to study how forest ecosystems are influenced by climate change and drought. Since 1981, Tyson has experienced two extreme droughts: the second-most severe drought in Missouri in the last 50 years (1988 drought) and the most severe drought in Missouri's recorded history (2012 drought).

Photo: Jonathan Myers

With support from Tyson Research Center and the International Center for Advanced Renewable Energy and Sustainability (I-CARES) at Washington University, researchers are using pre- and post-drought surveys of the Tyson Plot to address three key questions at the interface of ecology, ecosystem science, and environmental sustainability:

- Are climate change, drought, and tree mortality causing Ozark forests to shift from carbon sinks to carbon sources?
- To what extent can variation in functional traits among trees species explain drought-forest dynamics in heterogeneous landscapes?
- Do temperate and tropical forests respond similarly to drought?

Answers to these questions will help scientists project future forest health for policy makers and the public.

FDP highlights from the 2014 summer field season

Record-breaking team: The 15-person summer field team was the largest in the history of the project. The team included two graduate students, four undergraduate students from Washington University, an international student from Brazil, five high school research fellows, and eight additional high school students that participated in the project through the Missouri Botanical Garden's Shaw Institute for Field Training.

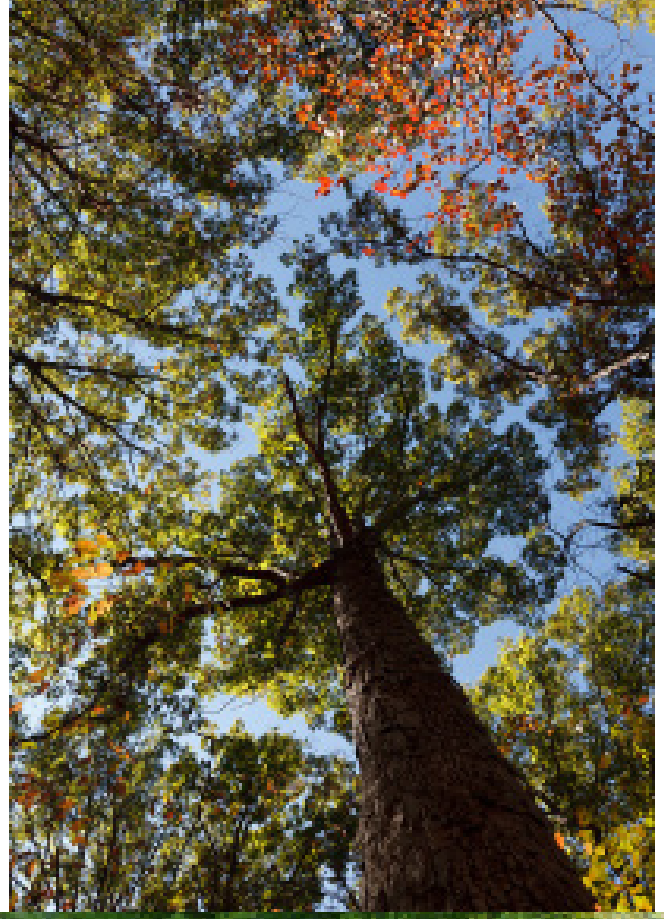
3*3 years of tree mortality, 3 years of seed rain, and the first annual seedling survey*: The field team surveyed >30,000 trees to quantify short-term and long-term responses of tree mortality to drought, completed a three-year survey of seed rain in 200 seed traps distributed across the plot, and initiated a long-term study of seedling recruitment and survival in 600 smaller monitoring plots in the forest understory.

First mammal survey: Tyson researchers Maranda Walton and Dr. Stephen Blake deployed camera traps in and around the plot to document the presence and abundance of mammals and birds. The images will soon be uploaded to the ForestGEO camera trap database for comparative studies of vertebrate biodiversity worldwide.

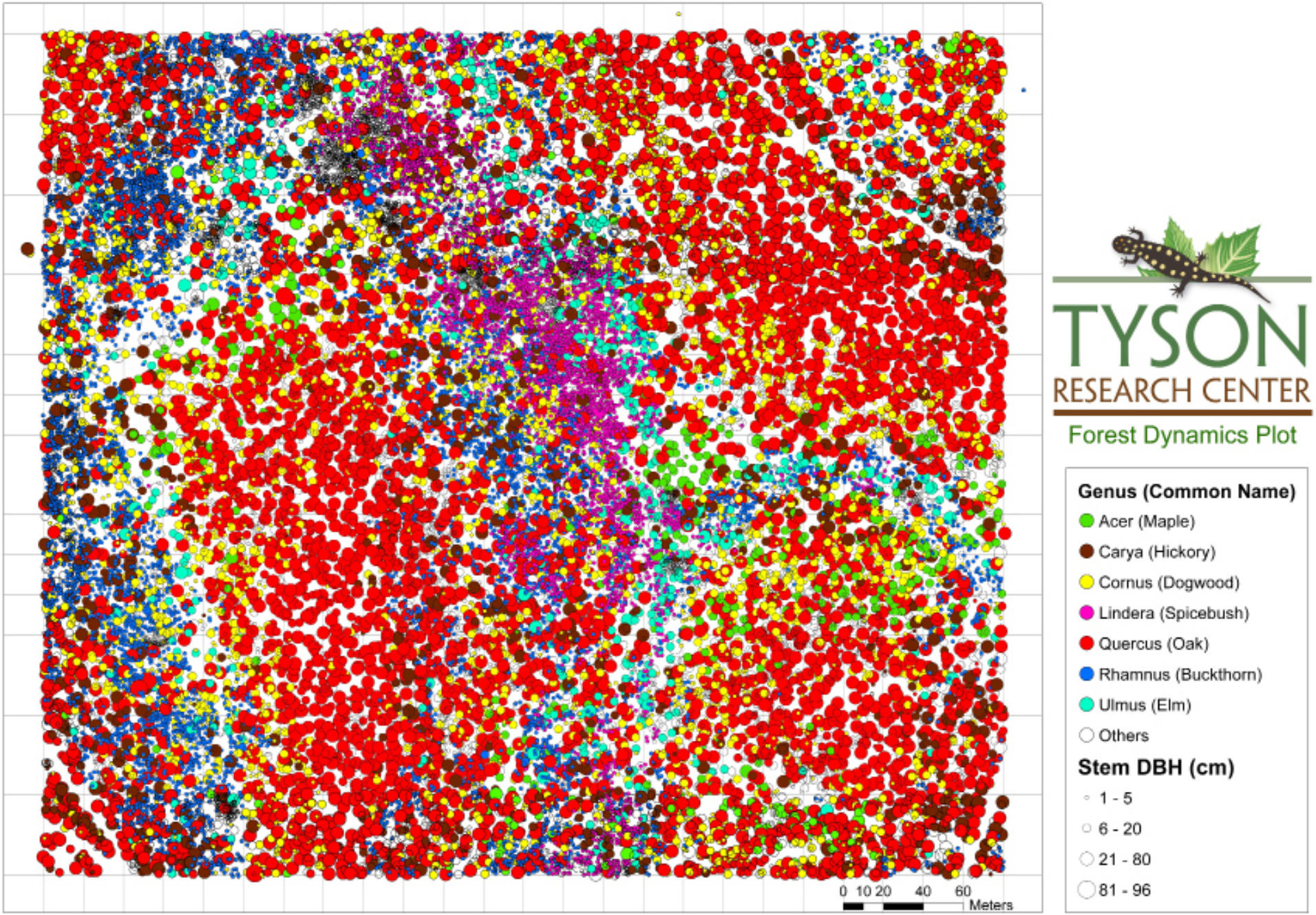
FDP highlights from the 2014 summer field season (cont.)

Cross-continental field studies: Tyson post-doctoral associate Dr. Marko Spasojevic was awarded a grant from the Smithsonian CTFS-ForestGEO Grants Program for a comparative study of plant functional traits across ForestGEO plots in western, central, and eastern North America. Together with Washington University graduate students Chris Catano and Dilys Vela, Spasojevic's team measured leaf traits on >1,500 trees of 80 species.

ForestGEO workshop in China: Dr. Jonathan Myers participated in an analytical workshop, "Diversity and Forest Change: Characterizing functional, phylogenetic and genetic contributions to diversity gradients and dynamics in tree communities", at the Xishuangbanna Tropical Botanical Garden in southwest China. The 55 workshop participants included students, early-career professors, and research associates from 20 countries.



Photos: Jonathan Myers



Map of tree species measured, identified, and geo-referenced over three summers in the FDP.

Soil-borne Pathogens and the Ecosystem Function of Plant Communities

Scott Mangan, Assistant Professor
Washington University, Department of Biology

Identifying the mechanisms that lead to the organization and function of biological communities is a fundamental goal in ecology. Many of the major theories in plant ecology have centered solely on competitive interactions. However, plants are associated with a wide-variety of microbes that directly influence their fitness. One of the major foci of our research at Tyson is to re-evaluate classic themes in plant ecology within the context of microbial interactions.

It is often observed that plant communities of high diversity are more productive than those of low diversity. The textbook explanation to this positive diversity-productivity relationship is that plant communities containing many individuals of few species suffer from high intraspecific competition, leading to lower overall productivity. The opposite is the case for plant communities of high diversity because they contain few individuals of many species, each differing in their resource requirements and acquisition strategies that allows for more efficient community wide use of available resources.

Tyson Research Scientist, Claudia Stein, and I are evaluating whether positive diversity-productivity relationships are better explained through plant-microbial interactions. With a grant from the International Center for Advanced Renewable Energy and Sustainability (I-CARES), we are testing an alternative hypothesis that ecosystem functions of species-poor plant communities suffer from a build-up of species-specific soil-borne pathogens, much like agricultural fields that contain the same crop species year after year.

In communities that contain fewer individuals of many species, such accumulation of specific pathogens is limited and ecosystem function will be higher. We are also testing whether communities that contain the same number of species, but differ in their phylogenetic relatedness fundamentally differ in their microbial-mediated ecosystem function.

In the summer of 2014, our team established a fully factorial mesocosm experiment designed to untangle the role of competition from that of plant-microbial interactions on ecosystem functioning of Missouri prairie plant communities. Three semi-truck loads of soil were steam sterilized and distributed among 160 eighty-gallon mesocosms, half of which received a live soil inoculum. Productivity of established plant communities differing in both species richness and phylogenetic relatedness will be monitored over at least the next three years. In collaboration with David Fike (Department of Earth and Planetary Sciences) and Mike Tobin (University of Houston- Downtown), we will measure other ecosystem functions such as nutrient cycling and community wide resilience to drought.

Interaction Between Fire and Exotic Species

Rae Crandall, Post-doctoral Associate
Washington University, Knight Lab

Exotic species can often invade and subsequently dominate communities in which they are not native, particularly when the disturbance regime of the native habitat has been significantly altered. For example, in many areas throughout the world, humans have altered the fire regime in natural communities (typically by fire suppression), and this often leads to dominance by non-native species. Although fire is frequently reintroduced to these systems under the guise of restoring communities to their native state, often little is known about the effects of fire on invasive species, making it difficult to predict how communities will respond. The success of an invasive plant following fire is predicted to depend on the invasive plant's response to fire, aspects of the fire regime, and presence of co-occurring fire-adapted plants, such as native perennial grasses. To test this prediction, Dr. Tiffany Knight and I are examining how Lespedeza cuneata, an invasive legume, and the native plant community responded to prescribed fires during different phases of L. cuneata and the native community's development (early June, mid-July, October, January). Within plots, we used a split-split design to also test for effects of dominant prairie grasses, *Schizachyrium scoparium* and *Androgogon gerardii,* and increased fire intensity (i.e., increased fuel loading). Preliminary results suggest that *less intense fires during the early growing season and the presence of perennial grasses decrease fecundity of L. cuneata and increase recruitment of native forbs from the seed bank. Without the presence of established, perennial grasses, L. cuneata is more likely to survive and regenerate quickly following fire and out-compete slower-growing native forbs that resprout or reseed.*

Fire and the presence of invasive species should interact to affect native plant populations and community composition. In oak-hickory forests, recurrent fires benefit populations of native species and increase species richness. The presence of exotic plants has the opposite effect; many native species are out-competed by exotic species and species richness decreases. We are investigating how these contrasting disturbances interact in habitats with an invasive woody shrub (*Lonicera maackii*), herbaceous biennial (*Alliaria petiolat*a), or tree (*Ailanthus altissima*) to control native plant populations and community composition. Results from this ongoing study will help land managers make informed decisions before using fires to restore degraded habitats where native and exotic species co-occur.

We are using data and observations from these manipulative field studies to develop mathematical models that predict the effectiveness of fire in restoration of habitats invaded by exotic species. Although fire exclusion is a primary mechanism by which exotic species can come to dominate native communities, reintroducing historical fire regime to restore native communities has only been moderately successful. This suggests there may be a critical transition or 'tipping point' between the native and exotic communities. We reviewed the literature and found that positive frequency dependence (PFD) (e.g., allelopathy, plant-soil feedbacks) is an important process for many invasive species and hypothesized that this might mediate restoration success. *Using a spatially-explicit individual-based model, we show that three factors control the likelihood by which reintroducing disturbances will tip the balance between native and exotic dominance: (1) the relative fitness' of native and exotic species, (2) the density and spatial aggregation of the exotic species prior to the onset of restoration, and (3) the magnitude of frequency dependence of the exotic species. We find that reintroduction of disturbances can restore a system only when PFD of the exotic species is weak, disturbances are frequent, and/or exotic species are not dominant or aggregated in the community.* Our framework provides guidelines for conditions in which the reintroduction of disturbances will effectively restore degraded systems invaded by exotics.

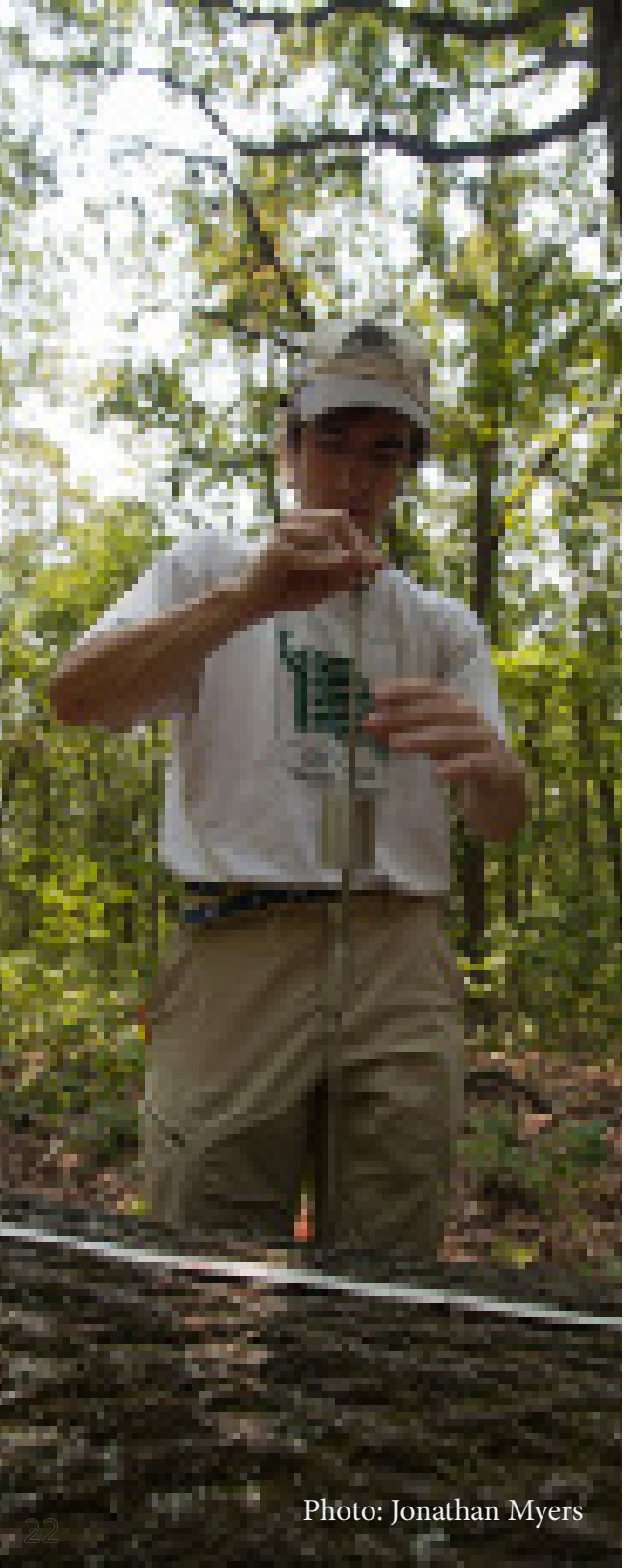


Photo: Jonathan Myers

Influences of Plant Traits on Wood Decomposition Rates Across Scales: From Fungal Microbe Communities to Carbon Turnover

Brad Oberle, Post-doctoral Associate

How did you survive the record-breaking summer heatwave of 2012? Did you duck ten consecutive days of triple-digit temperatures by cranking down your AC? Was your chair closer to the pool during the driest summer in Missouri's recorded history? Whatever your answer, you should plan on more of the same. Climate models for the Midwest predict increasing temperatures and higher risk for summer drought in the decades to come.

While you beat the heat with technology, native plants and animals had no such luxury. Leaves drooped, seedlings shriveled and animals clustered around vanishing waterholes. With model predictions what they are, the forests in 2012 could look very much like the forests of the future with one major exception: species that can't take the heat will be out of the proverbial kitchen.

Why should we care whether species win or lose as climate changes in Missouri forests? Globally, forests absorb and store tremendous amounts of carbon dioxide, the same greenhouse gas emitted by fossil fuel use. For example, Missouri White Oaks (*Quercus alba*) collectively store as much carbon dioxide as the annual emissions of the entire US commercial air fleet. Trees store most carbon as wood, a valuable natural product that varies in quality from one species to the next. When extreme weather stresses trees to death, their wood begins to rot, releasing carbon dioxide back into the atmosphere where it can amplify the effects of global warming. Predicting which tree species are mostly likely to die and decay has huge implications for managing Missouri forests for sustainable timber harvest and maximum carbon sequestration.

My research focuses on the biology of climate change by using species' responses to historical climate change to predict and prepare for likely changes in the future. For the past several years, I focused on how wood traits, such as density and chemistry, influence how forests at Tyson respond to extreme weather. A main question driving my work is whether particular wood traits link mortality and decay. For instance, wood transports water from roots to leaves via microscopic vessels. Long vessels can spread tiny tree-choking air embolisms during drought. If the tree dies, the same vessels may act as highways for the slender filaments of wood-rotting fungi. Traits like this may make some species liable to die and decay quickly after a major drought. Resource managers can plan for future forests by focusing on these pivotal species.

Working with Amy Zanne, an expert on wood traits at The George Washington University, I have been measuring how trees at Tyson build their wood and how their decomposers destroy it. To see the forest for these trees, I am working with Jonathan Myers at Washington University to examine how trees survived droughts in the Tyson Forest Dynamics Plot during the last 30 years. Finally, to connect all of the pieces, I have worked with many other researchers, students and technicians to build new statistical models and dead wood datasets.

Our results are starting to reveal how some trees survived the 2012 drought and what we might expect to happen to the rest. ***Tree species that died rapidly following the 2012 drought are the same ones that fared poorly during other recent droughts.*** Generally, these species have traits and occupy habitats that make them especially vulnerable. However, the traits that predispose certain trees to die during drought differ from traits that cause some species' wood to decay quickly. For instance, vessel length strongly impacts death during drought but has almost no effect on decay. As a result, the composition of dead trees at Tyson today differs from that of living trees and reflects the overabundance of both drought-sensitive and decay-resistant species.

These results are just the tip of the (melting) iceberg. In collaboration with researchers at the Yale School of Forestry, we are exploring how dead wood produces other greenhouse gasses. Also, with colleagues from James Cook University in Australia, we are conducting 'autopsies' on trees that died during the drought by using small portions of wood to assess their growth during the preceding decades. Our work has already contributed to a climate change impact assessment for Missouri forests. While I ask how lessons learned at Tyson apply to other forests globally, you may want to ask yourself: how will you survive the next record-breaking heatwave?

Photo: Jonathan Myers

Movement Ecology

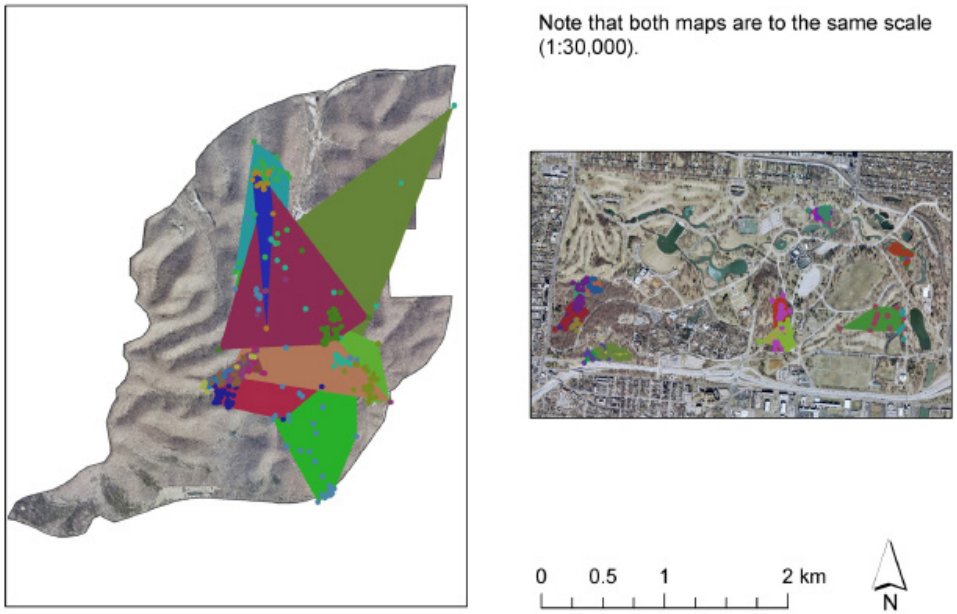
Steve Blake
Max Planck Institute for Ornithology
Honorary Research Scientist, Washington University in St. Louis

Renowned biologist Archie Carr one said that "Everyone loves turtles." Be that as it may, evidence is strong that turtle populations are in decline throughout the US (and the rest of the globe) because of the usual suspects; over-harvesting, road kill, habitat loss, and disease. The humble three-toed box turtle, Missouri's state reptile, is likely no exception though population trajectories are hard to determine. Three years ago, we became aware that box turtles were resident in St. Louis' Forest Park, arguably the finest urban park in the US. The turtles, a priority for park managers, live in small forest fragments varying in size, shape, isolation and human impact, and distributed through the multi-use park – a wonderful little island biogeography archipelago. At about the same time we realised that some 25km away, the heavily wooded Tyson Research Center provided an ideal "natural" site in which to conduct comparative research on urban (Forest Park) versus rural turtles. Together the two sites could also offer excellent opportunities for outreach and environmental education for local St. Louisans, using turtles as ambassadors for nature and science. To these ends, we began studying the movements and health status of box turtles at the two sites. Turtles are fitted with radio-transmitters and tracked every week to record their location, body weight and carapace measurements and to conduct visual examinations. Blood samples are taken annually to quantify basic haematology, blood chemistry, and exposure to infectious diseases.

Nicely supporting our initial hypothesis, we have found that the ***Forest Park turtles have small home ranges*** (mean 2.6Ha) *compared to the Tyson turtles* (mean 75.7Ha), and are largely confined to their forest fragments. Tyson turtles are wanderers, with home ranges up to 236Ha, the biggest ever recorded for box turtles. Three of our tagged turtles have left the confinesof Tyson, with one individual, Kevin, consistently occupying the grass verge of interstate highway 44! An 810Ha private reserve is too small for box turtles! Our movement data indicate that even the most sedentary of the turtles, with a home range of just 1Ha, would, if placed at a random location in suitable habitat anywhere in Missouri, have a ***>60% chance of crossing a road at least five times in a year***, while the wide ranging Tyson turtles would have a ***90% of crossing roads at least 10 times***. Despite the wild Ozark Forests, it seems that turtles are not safe anywhere in Missouri.

In contrast to our hypothesis that the health status of Forest Park would be lower than those at Tyson, we found that turtle body condition, stress levels, and haematology were similar between the two sites. *Evidence of physical trauma (dog bites, shell deformities, skin lesions etc.) was however more frequent at Forest Park, while Tyson turtles appear to have higher prevalence of infectious diseases*, perhaps because the contiguous habitat and large scale movements facilitate transmission.

As usual, our research is posing more questions than it is providing answers, making excellent fuel for our box turtle outreach program. Over 20 undergraduates and literally hundreds of elementary, middle and high school students have participated in our project in a variety of ways, from deep immersion in the research program to a casual educational turtle "safari" on a summer day. We plan to expand both our research program to generate results of real value for conservation in Missouri, and the outreach program to increase the relevance of box turtle well-being for the citizens of St. Louis, the state of Missouri and beyond.



Box turtle home ranges at Tyson Research Center (left) and Forest Park (right). Ranges are color coded by individual turtle.

Tyson Monitoring Programs

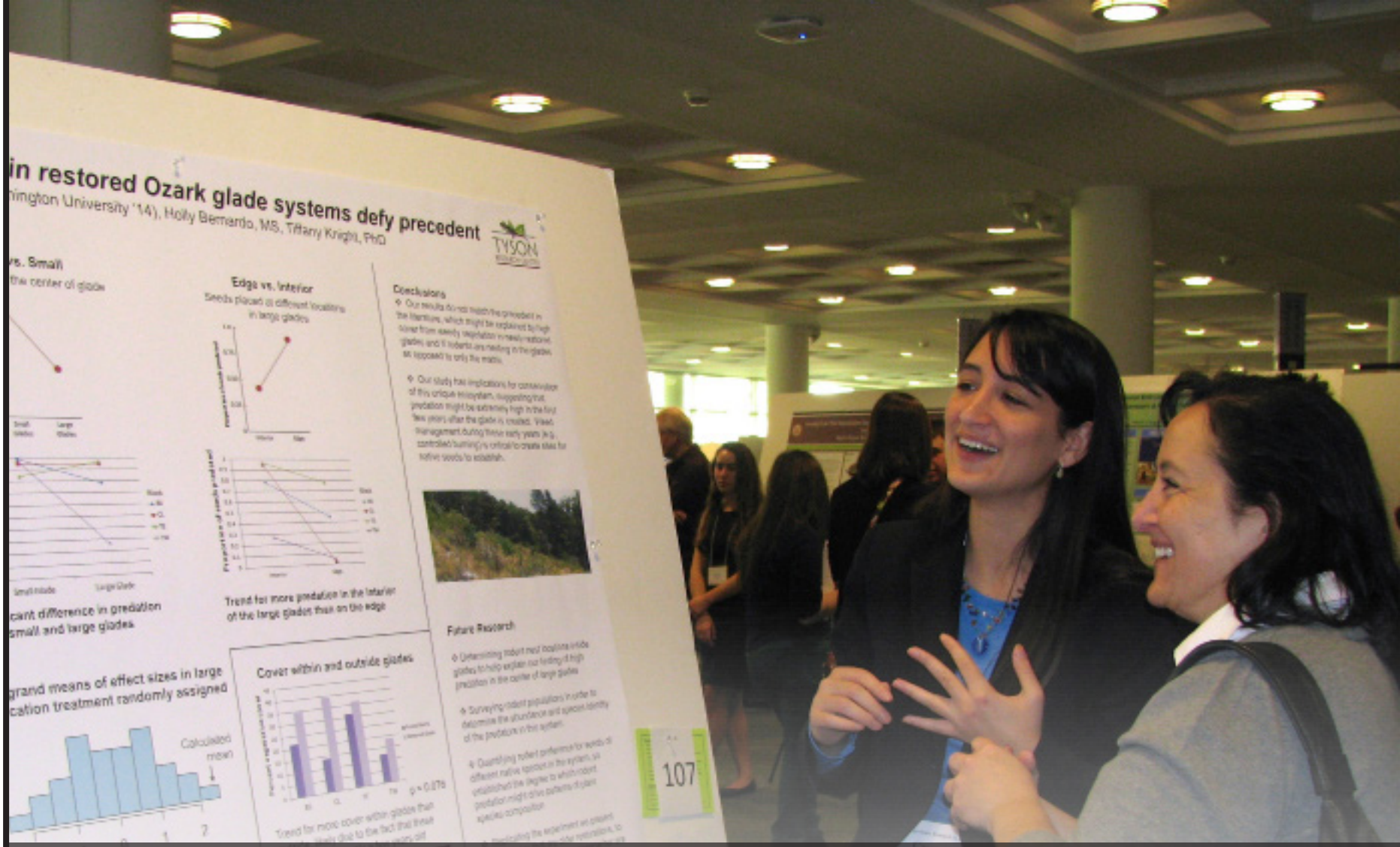
Pond Diversity Network: The Tyson Pond Diversity Network contains archived data on flora, fauna and environmental characterisitics of pond ecosystems at Tyson and numerous natural areas within a 2-hour radius of the St. Louis metropolitan area. Since 2007, Tyson has coordinated annual data collection within the network with assistnace from graduate, undergraduate, and high school students. The database includes species presence and abundance, abiotic measurements, photos, water chemistry data, and other notable observations. This database serves as a resource to monitor changes in regional aquatic biodiversity and for researchers seeking out baseline data to inform research.

GIS Database: The Tyson GIS Database is a collection of geo-spatial data within Tyson and landscapes adjacent to Tyson. The baseline data for this database includes areas of active research at Tyson, facilities, roads, trails, property lines, and other environmental features that researchers and staff can use to plan projects. In addition to the baseline data, GIS data is created and collected by Tyson researchers and stored for current and future use (e.g. topography, elevation, land use and geology data).

Photo Archive: For over 8 years, we have collected more than 10,000 photos of plants, animals, and ecosystems at Tyson into a digital herbarium and museum. This collection serves as a historic voucher database of species occurrence, and allows researchers to cross-check species they are identifying in the field.

Dendrochronology Library (new program): In summer 2014, Tyson began collecting and curating tree "cookies", cross-sections of trees that have fallen during storms or other natural means. By building a repository of wood samples from fallen trees we can determine how past climate fluctuations, particularly known drought events, affect tree growth. The results will allow researchers to better predict variation in tree species' responses to anticipated climate change.

EDUCATION & OUTREACH



"As ecological research at Tyson has grown substantially in recent years, so has the opportunity for education and outreach. Environmental career exploration programs for college students and high school youth are aligned with the scientific research being conducted on site. Tyson coordinates three programs that provide for authentic engagement in research activities and access to scientists at a wide range of career stages."

Susan Flowers
Education and Outreach Coordinator

Tyson Undergraduate Fellows Program

In this 11-week summer program, undergraduate students are given the opportunity to work elbow-to-elbow with a faculty, post-doctoral scientist, staff scientist, or graduate student mentor on current field-based research projects. First-time fellows typically have interest in ecological research but may not yet have the experience needed to conduct their own mentored research projects. Advanced or returning undergraduate fellows are often given the opportunity to design and execute their own field-based ecological research under the guidance of a mentor.

After completion of the summer field season, fellows often present the results of their research at either the WUSTL undergraduate research symposium or another similar symposium at their own undergraduate institution. Former fellows have presented their research at regional and national meetings and several projects have resulted in peer-reviewed publications. Many of our former fellows have entered graduate programs or careers in the environmental sciences. Support for the Tyson Undergraduate Fellows Program is provided by NSF grants, HHMI funds, internal WUSTL fellowship and internship funds, and Tyson Research Center.

Undergraduate fellow activities – Fall/Winter 2013-14

Seven of the 22 undergraduate fellows from summer 2013 presented posters at the WUSTL fall 2013 undergraduate research symposium.

Cassandra Galluppi, WUSTL '14
Rodent predation patterns in restored ecosystems depend on habitat size (Dr. Tiffany Knight, WUSTL)

Anna Liang, WUSTL '16
Can feeding preferences of exotic snails contribute to the success of invasive species? (Dr. Scott Mangan, Dr. Claudia Stein, WUSTL)

Amy Patterson, WUSTL '15
Mechanisms of invasion: How invasive species eclipse the competition (Dr. Tiffany Knight, WUSTL)

Eleanor Pearson, WUSTL '14
Perennial grasses and droughts interact to influence diversity and growth of native plants (Dr. Tiffany Knight, WUSTL)

Ameila Snyder, WUSTL '15
Balancing the beneficial and limiting results of fire on bee diversity in the Ozark mountain glades of southern Missouri (Dr. Tiffany Knight, WUSTL)

Emily Stein, WUSTL '14
Growing beyond the classroom: The role of the educator in informal science education (Susan Flowers, WUSTL Tyson Research Center)

Alyssa Wilson, WUSTL '15
Pollination in restored glades (Dr. Tiffany Knight, WUSTL)

Shaw Institute for Field Training (SIFT) Program

Through collaboration with the Missouri Botanical Garden's Shaw Nature Reserve, local teenagers in the SIFT program may assist Tyson-based researchers with projects during the summer field season and sometimes within the academic year. SIFT is an introductory field skills training program that engages participants in scientific exploration of the natural world and includes opportunities to help with real fieldwork. Accepted participants come from a wide cross-section of the St. Louis, Missouri community including urban, suburban, and rural areas. To date, seven cohorts have participated in SIFT, for a total of 291 students from 64 separate high schools and homeschool.

C6 SIFT activities at Tyson – Fall/Winter 2013-14

During October 2013, cohort six SIFTers were able to help graduate student Jason Bohenek close down his newt mesocosm study (Texas Tech University, Resetarits Lab). Sixteen SIFTers attended the TERF symposium at Tyson on January 25, 2014.

C7 SIFT activities at Tyson – Summer 2014

After completing their week-long training in June, cohort seven SIFTers were invited to help out on a number of projects at Tyson. Five research teams hosted a variety of SIFT work days during summer 2014.

- Sorting of samples from glade insect survey (Holly Bernardo, WUSTL Knight Lab)
- Measurement of invasive plant leaf traits (Sam Levin and Tyler Pokoski, WUSTL Knight Lab)
- Assessment of seeds and inflorescences on invasive plant species (Sam Levin and Amibeth Thompson, WUSTL Knight Lab)
- Box turtle movement tracking and health assessment (Steve Blake, WUSTL and Jamie Palmer, St. Louis Zoo Institute for Conservation Medicine)
- Large-scale forest dynamics plot mortality census (Maranda Walton, WUSTL Myers Lab)
- Phylogenetic diversity study (Claudia Stein and Eleanor Pearson, WUSTL Mangan Lab)
- Generalist herbivore study (Claudia Stein and Eleanor Pearson, WUSTL Mangan Lab)

Tyson Environmental Research Fellowships (TERF) Program

During the summer, successful graduates of the SIFT program may apply to work for at least four weeks as members of research teams alongside WUSTL scientists, post-doctoral researchers, technicians, graduate students, and undergraduate students. The TERF program provides a cultural apprenticeship in university-based environmental biology research and training in scientific communication. It is an advanced summer experience modeled on Tyson undergraduate research internships, including journal article discussion, seminars by visiting scientists, and stipend support. Fall and winter activities are designed to provide important community outreach, emphasizing the value of environmental research. TERFers work with their mentors to develop scientific posters and present results of research at the Washington University fall undergraduate symposium and a winter TERF symposium at Tyson. Some are invited to present at their high schools and many enter honors divisions for local and regional science fairs. To date, 103 high school level summer internships have been provided. Sixty percent of the students who have participated in TERF are female and 20% are from ethnic groups underrepresented in STEM.

C5 TERF activities – Fall/Winter 2013-14

Seventeen cohort five TERFers from 14 different high schools were hosted at Tyson during summer 2013. Two were returning for a second summer. For several weekends in September and October, TERFers gathered at Tyson to work on data analysis and poster construction with guidance from their research mentors. The resulting eleven TERF posters were indistinguishable from those generated by undergraduates and made up 5% of the total posters in the WUSTL fall 2013 undergraduate research symposium held on October 26, 2013. This group of TERFers presented their posters again, along with formal slide presentations, during their own TERF Symposium held at Tyson on January 25, 2014.

TERF posters - Fall/Winter 2013-2014

Ben Banet, Saint Louis University High School '14
Study of box turtles in St. Louis urban and suburban environments indicates significant differences in home ranges (Dr. Stephen Blake, WUSTL)

Andrew Feltmann, St. Francis Borgia High School '14
Removal of an invasive species, bush honeysuckle, increases deer usage but only in unburned habitats (Dr. Raelene Crandall, WUSTL)

George Garner, Ladue Horton Watkins High School '15
Removal of an invasive species, garlic mustard, influences recruitment of woody plants (Dr. Raelene Crandall, WUSTL)

Madeline Herries, Nerinx Hall '14
Adam Rangwala, Clayton High School '14
Investigating box turtle health and communicating findings using social media (Dr. Stephen Blake, WUSTL)

Clayton Hillermann, Eureka High School '15
Hannah Walkowski, Fort Zumwalt North High School '15
Effect of soil variation on tree species diversity in a forest community (Maranda Walton, Dr. Jonathan Myers, WUSTL)

Hannah Kruse, Fort Zumwalt North High School '15
Fire increases invasive species germination but not survivorship (Erynn Maynard, Dr. Tiffany Knight, WUSTL)

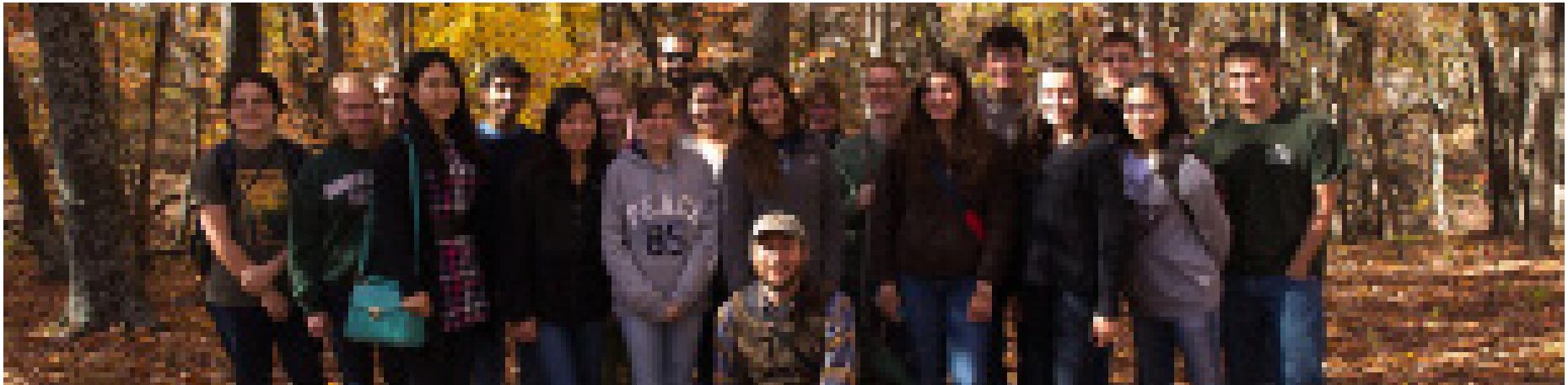
Leyna Stemle, Marquette High School '14
Plant extinctions in newly restored glades can be attributed to stochastic processes (Holly Bernardo, Dr. Tiffany Knight, WUSTL)

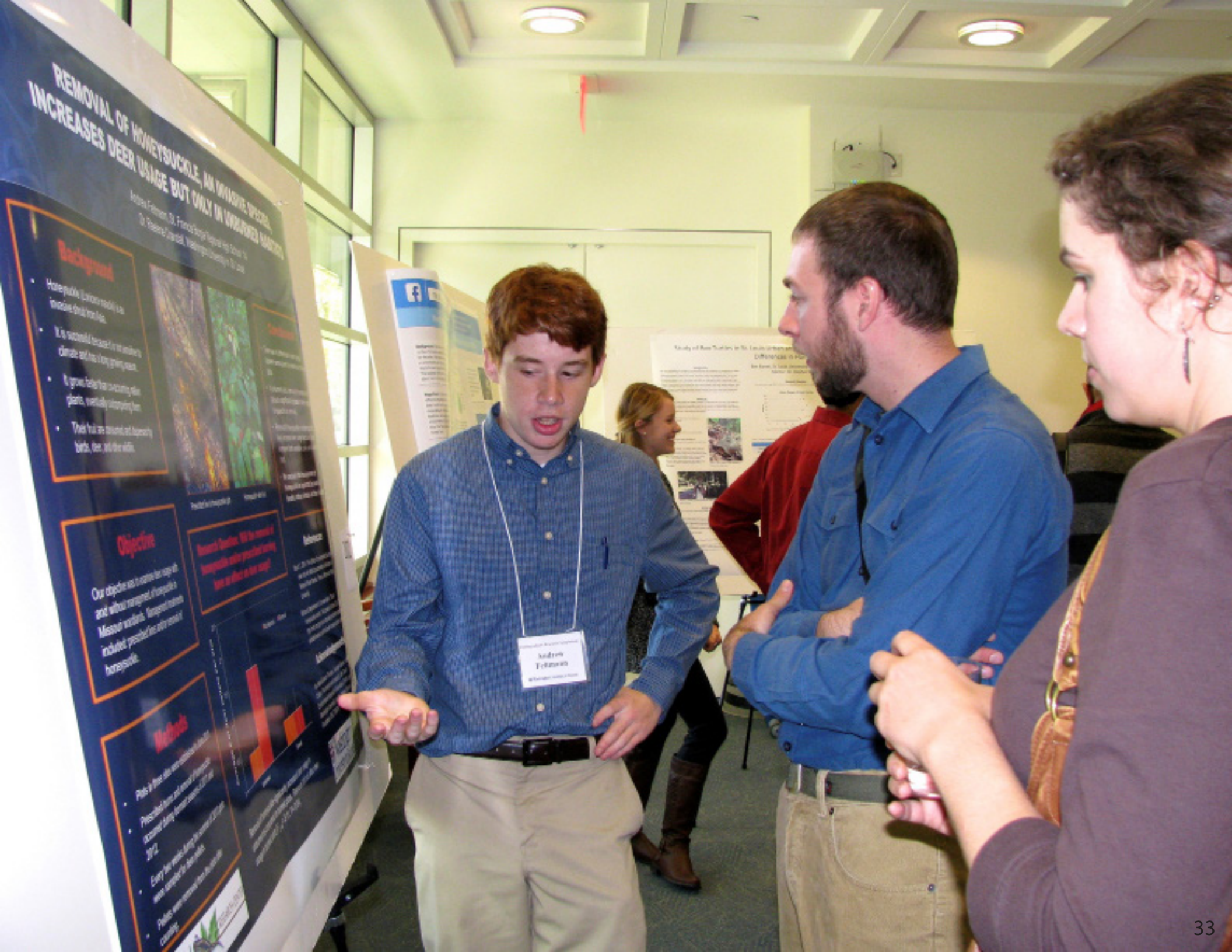
Ellen Sulser, Kirkwood High School '14
Adam Vorel, Eureka High School '15
Die-off and recruitment of tree multi-stems after drought (Maranda Walton, Dr. Jonathan Myers, WUSTL)

Thomas Van Horn, Thomas Jefferson School '14
Fire effects on herbivory of invasive plant species (Erynn Maynard, Dr. Tiffany Knight, WUSTL)

Courtney Vishy, Francis Howell High School '14
Anthropogenic disturbance increases exotic species abundance (Erynn Maynard, Dr. Tiffany Knight, WUSTL)

Maddie Willis, Marquette High School '14
Rodents show preference for seeds of certain native glade species (Holly Bernardo, Dr. Tiffany Knight, WUSTL)




REMOVAL OF HONEYSUCKLE, AN INVASIVE SPECIES,
INCREASES DEER USAGE BUT ONLY IN UNBURNED HABITATS
Background
Objective
Methods

2014 SIFT & TERF alumni weekend

SIFT & TERF Alumni Weekend – July 26-27, 2014

Participants from cohorts 1-6 of the SIFT and TERF programs were invited to return to Tyson and Shaw Nature Reserve for an alumni weekend at the end of the 2014 field season. They toured the renovated Tyson headquarters building and new research laboratory before heading to Shaw for a field challenge course and career panel made up of Dr. Kim Medley (Tyson Research Center), Jean Turney (education, Forest Park), Cassi Lundeen (Nature Works program, Forest Park), and Rebecca Ewing (Mark Twain National Forest, USDA Forest Service).

Missouri Environmental Education Association Award

The SIFT and TERF programs were awarded the 2013 Outstanding Service Award from the Missouri Environmental Education Association (MEEA) in recognition of promoting environmental education in Missouri. Susan Flowers accepted the award on behalf of Tyson Research Center and Shaw Nature Reserve during the 2013 Missouri Environmental Education Conference on November 2, 2013 at Blue Ridge Elementary School in Columbia, Missouri.

FACILITIES & DEVELOPMENT

New Facilities

Summer 2014 marked the first field season that research teams used the newly constructed laboratory building. This ~4000 ft^2 facility, built under an existing warehouse structure, houses two dry labs for sample sorting and processing, a wet lab, a molecular and chemistry lab, and a microscope room. This space has become essential for research teams coupling field and lab work. Open areas around and behind the lab serves as outstanding covered work space for experimental prep, growing seedlings, and working with larger field samples.

During 2014, we completed construction of an NSF-funded research garden. The 1400 m^2 garden is divided into five 16m x 18m sections containing a prairie soil mix. Three of the sections have posts to mount panels or fabric for rainout material, shade cloth, or screening to limit pollination. The garden is irrigated by rainwater supplied by a new collection system (see left). Rainwater is captured from the warehouse roof and stored in eight tanks capable of storing a cumulative volume in excess of 20,000 gallons, which is pumped to the garden on demand.

Sustainability

Wise use of our natural resources is important to Washington University and Tyson. The 2009 construction of our Living Learning Center, a certified "Living Building", kick-started our campaign to operate more sustainably. During 2014, the WUSTL Office of Sustainability coordinated a multi-campus scattered solar project; as a part of this project, Tyson received an additionl 50 kW of of solar power. The two 25kW arrays (above) supply green energy to our headquarters building and to the new lab. As a result of our green-energy expansion, we now exceed 30% locally generated green power across the entire Tyson campus. In recognition of this acheivement, we were recently named a Green Power Partner by the US Environmental Protection Agency. We continue to improve our efficiency by closely monitoring our energy useage and by making small-scale retrofits such as converting low-efficiency lighting systems to LED, and are working on additional ways to improve our campus-wide sustainable operations.

Sustainability
Washington University in St. Louis

EPA GREEN POWER PARTNER

Living Learning Center

Appendix A: Research Use 2013-2014

Summary of institutions, faculty, students, and staff that utilized Tyson Research Center.

Institution	Faculty	PD	Grad	Tech	UG	HS	NSF-funded projects	NIH-funded projects	I-CARES supported projects
Washington University in St. Louis									
Biology	6		8	2	17	29	5		2
Tyson	1	2		2	3		1		
Environmental Studies	1	1							
Earth & Planetary Sciences	1								1
Physics	1		2						
Sam Fox School	1								
Performing Arts	2								
Saint Louis University	1		1				1		
University of Missouri St. Louis	1		1		1				
Illinois State University	2		9				1	1	
Texas Tech University	1		4		1		1		
Davidson College	1				2		1		
Case Western Reserve			1						
The George Washing ton University	1	1		1			1		
Max Planck Institute for Ornithology	1				2	4	1		
St. Louis Zoo	1			1					
University of Houston	1*								

PD: post-doc, Grad: graduate student, Tech: staff technician, UG: undergraduate (WUSTL or other), HS: high school youth. Projects funding is shown as follows: NSF (National Science Foundation), NIH (National Institutes of Health), I-CARES (International Center for Advanced Renewable Energy and Sustainability).

Appendix B: Publications 2013-2014

2014 Schuler, M.S., J.M. Chase, and T.M. Knight. More individuals drive the species-area relationship in an experimental zooplankton community. Oikos DOI: 10.1111/oik.01931

2014 Spasojevic, M. J., E. A. Yablon, B. Oberle, and J. A. Myers. Ontogenetic trait variation influences tree community assembly across environmental gradients. Ecosphere 5(10):129. http://dx.doi.org/10.1890/ES14-000159.1

2014 Medley, K. A., Jenkins, D. G. and Hoffman, E. A. Human-aided and natural dispersal drive gene flow across the range of an invasive mosquito. Molecular Ecology. doi: 10.1111/mec.12925

2014 Anderson-Teixeira, K.J, et. al. CTFS-ForestGEO: a worldwide network monitoring forests in an era of global change. Global Change Biology (2014), doi: 10.1111/gcb.12712

2014 Beck, J. B., Ferguson, C. J., Mayfield, M. H., Shaw, J. Reduced genetic variation in populations of black cherry (Prunus serotina subsp. serotina, Rosaceae) at its western range limit in Kansas. Northeastern Naturalist 21(3):472-478.

2014 Chung, Y. A., Burkle, L. A., Knight, T. M., Minimal Effects of an Invasive Flowering Shrub on the Pollinator Community of Native Forbs. PLoS ONE 9(10): e109088. doi:10.1371/journal.pone.0109088

2014 Spasojevic, M. J.,Yablon, E. A., Oberle, B., Myers, J. A. Ontogenetic trait variation influences tree community assembly across environmental gradients. Ecosphere 5:art129.

2014 Burgett, A. A. and Chase, J. M. Landscape context influences the abundance of amphibians and the strength of their food web interactions in small ponds. Oikos. doi: 10.1111/oik.00951

2013 Hopwood, J.L., Flowers, S.K., Seidler, K.J., Hopwood, E.L. Race to Displace: A Game to Model the Effects of Invasive Species on Plant Communities. The American Biology Teacher. 75(3), 194-201

2013 Powell, K.I., J.M. Chase, & T.M. Knight. Invasive plants have scale-dependent effects on diversity by altering species-area relationships. Science 339: 316-318.

2013 Reeves, M. K., Medley, K. A., Pinkney, A.E., Holyoak, M., Johnson, P. T. J., Lannoo, M. J. Localized hotspots drive Continental geography of abnormal amphibians on U.S. wildlife refuges. PLoS ONE (8)11: e77467

2013 Shyu, E., Pardini, E.A., Knight, T.M. A seasonal, density-dependent model for the management of an invasive weed. Ecological Applications.

2013 Michel, M.J. and Knouft, J.H. Accepted. Spatial structure and the temporal transferability of trait-environment relationships. Landscape Ecology.

2013 Murrell, E. G., Juliano, S. A. Predation resistance does not trade off with competitive ability in early-colonizing mosquitos. Oecologia 173 (3), 1033-1042

2013 Strauss A., Smith, K. G. Why Does Amphibian Chytrid (Batrachochytrium dendrobatidis) Not Occur Everywhere? An Exploratory Study in Missouri Ponds. PLoS ONE 8(9): e76035. doi:10.1371/journal.pone.0076035

2013 Burns, J. H., Pardini, E. A., Schutzenhofer, M. R., Chung, Y. A., Seidler, K. J., Knight, T. M. Greater sexual reproduction contributes to differences in demography of invasive plants and their noninvasive relatives. Ecology 94(5), 995-1004

2013 Bayles, B. R., Evans, G., Allan, B. F. Knowledge and prevention of tick-borne diseases vary across an urban-to-rural human land-use gradient. Ticks and Tick-Borne Diseases 4, 352-358

2013 Stanton-Geddes, J., Tiffin, P., Shaw, R.G. Insights from population genetics for range limits of a widely distributed native plant. American Journal of Botany 100(4), 744-75

Appendix C: 2014 Summer Seminar Series

May 15: Shalene Jha, University of Texas at Austin
Movement in the matrix: pollinator movement and population genetics across human-altered landscapes

May 22: Kyle Harms, Louisiana State University
Mechanisms maintaining species diversity in high-diversity tropical forests

May 29: Jennifer Gleason, University of Kansas
The evolution and genetics of courtship signaling and reception

June 5: Jonathan Losos, Harvard University
Experimental studies of evolution: research on lizard adaptation in the Bahamas

June 12: Brad Oberle, George Washington University
Tale from the crypt: dead wood dynamics and biodiversity effects in Ozarks forest carbon cycling

June 19: Toby Kellogg, Danforth Plant Science Center
Evolution of dispersal and pollination in ecologically dominant grasses

June 26: Jason Knouft, Saint Louis University
Global climate change, hydrology, and aquatic biodiversity

July 10: Dan Johnson, The Ohio State University
Patterns and mechanisms of forest regeneration dynamics

July 17: Stefan Schnitzer, University of Wisconsin Milwaukee
Lianas, trees, and the maintenance of species diversity in tropical forests

July 24: Steve Juliano, Illinois State University
Community ecology of water-filled containers: competition, predation, and disturbance influence mosquito production


ABF GAP families

Appendix D: Educational Use

Washington University

Architecture 317: Architectural Design I Landscape (Abbott, Gibson, Mueller, Murphy, Stouffer, Vogler)
Architecture 551A: Landscape Ecology (Ladd)
Architecture: Graduate studio
Biology 2431: Focus-Missouri's Natural Heritage (Braude)
Biology 419: Community Ecology (Myers)
Biology 4193: Experimental Ecology Laboratory (Mangan)
Chemical Engineering 408: Environmental Engineering Lab (Giammar)
Design and Visual Arts 317/417: Digital Imaging and Photography
Earth and Planetary Sciences 106: Freshman Seminar-Earth and Planetary Sciences (Fike)
Earth and Planetary Sciences 210: Earth and the Environment
Earth and Planetary Sciences 413: Introduction to Soil Science (Catalano)
Earth and Planetary Sciences 454: Exploration and Environmental Geophysics
Environmental Studies 290: Sophomore Seminar in Sustainability and the Environment (Parks)
Environmental Studies 393: Practical Skills in Environmental Biology Research (Stein, Spasojevic)
General Studies 160: The Tyson Seminar-Grounding Research in Nature (Loui)
University College-Biology 2351: Plants of Missouri
University College-Biology 524: Ecology and Environmental Sciences (Knight)
University College-Dance 213: Ecosomatic Practices-Contemplative Movement in Nature (Marchant)
University College-Environmental Literature: Topics in Environmental Literature-Nature and the American Literary (DeVoll)

Other University Courses

Fontbonne University, Field Ecology
St. Louis University, Soil Science
Webster University, Ecology

K-12 groups

McCluer High School turtle tracking trip
Pattonville High School turtle tracking trip
Principia Upper School
Signal Hill Science Club
WUSTL High School Summer Scholars tour
Youyh Exploring Science (YES, St. Louis Science Center) Teens turtle trip

Other (tours, conferences, retreats)

Arts & Sciences Communications Retreat (WUSTL)
BALSA group meeting (WUSTL Student group)
Blankenship Lab retreat (WUSTL)
Earthways Environmental Campers
Green Ambassadors (WUSTL Student group)
Hine's Emerald Dragonfly Conference
Missouri Prairie Foundation Bee Workshop
Movement Ecology Teacher Workshop (WUSTL)
Natural Sciences Administrator Group (WUSTL)
Plant and Microbial Biosciences Annual Retreat (WUSTL)
Soil, Water, and Plant Summit (WUSTL)
Wolf Species Survival Plan Meeting

Tall leadplant, Amorpha fruticosa

Appendix E: Tyson Undergraduate Fellows 2014

During summer 2014, Tyson hosted 12 undergraduate fellows from Washington University and 11 from other US universities including one international fellow. These 23 fellows conducted research on the following seven research teams:

Aquatic species declines and extinction
PI: Dr. Kevin Smith, Davidson College
Matthew Leong – WUSTL
John Overall – Davidson College
Thomas Pederson – Davidson College

Box turtle movement and health
PI: Dr. Stephen Blake, WUSTL
Kelly Kries – WUSTL
Briana Tiffany[1] – WUSTL

Experimental glades and insect communities
PI: Dr. Tiffany Knight, WUSTL
Kenneth O'Dell – McKendree University
Julia Steger – University of Tulsa

Invasive plant population dynamics
PI: Dr. Tiffany Knight, WUSTL
Tom Collins – Missouri University of Science & Technology
Samantha Hunkler – University of California, Berkeley
Amy Patterson – WUSTL
Tyler Pokoski – University of Iowa
Amibeth Thompson – Illinois College

Species interaction and invasion
PI: Dr. Scott Mangan, WUSTL
Corrine Amir – University of California, San Diego
Anna Liang – WUSTL
Amelia Snyder – WUSTL

Temperate forest dynamics and biodiversity
PI: Dr. Jonathan Myers, WUSTL
Jamal Gaddis – WUSTL
Mary Gardner[2] – WUSTL
Kate Harline – WUSTL
Eduardo Koerich Nery – Indiana University
Emily Wen – WUSTL

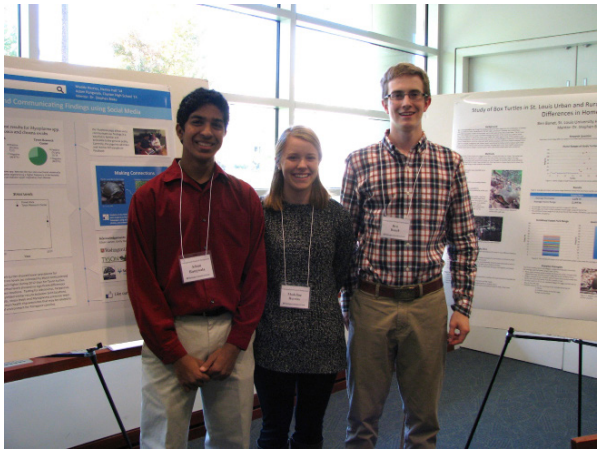
Urban ecology and epidemiology
PI: Dr. Kim Medley, WUSTL
Eleanor Moen – University of Illinois Urbana-Champaign
Amanda Kalupa – WUSTL
Anna Darling – WUSTL

1 Owen Sexton Fellow
2 Lennette Fellow

Appendix F: TERF Participants Summer 2014

Fifteen cohort six TERFers from 11 different high schools were hosted at Tyson during summer 2014. All are college-bound and six were returning for a second summer. One is now enrolled at WUSTL and three have been accepted early decision for matriculation in fall 2015.

Brenda Alvarado, Francis Howell North High School '15
Aiza Bustos, Francis Howell North High School '15
Alexander Connell, Francis Howell North High School '15
Ben Difani, Rockwood Summit High School '14
Clayton Hillermann, Eureka High School '15
Sarah Link, Eureka High School '15
Dasha Malkova, Ladue Horton Watkins High School '15
Sarah Monsey, Parkway North High School '15
Alexandra Porter, Rosati-Kain High School '15
Jacob Reitinger, De Smet Jesuit High School '15
Leyna Stemle, Marquette High School '14
Ellen Sulser, Kirkwood High School '14
Thomas Van Horn, Thomas Jefferson School '14
Adam Vorel, Eureka High School '15
Hannah Walkowski, Fort Zumwalt North High School '15



The following TERF posters are were presented at the WUSTL fall 2014 undergraduate research symposium and TERF symposium in January 2015:

- *Plants in small glade restorations have high reproductive success*
- *Habitat size and shape have variable effects on plant recruitment*
- *A ForestGEO Overview – Being Part of a Global Project*
- *Drought lag effects on temperate forest tree communities*
- *St. Louis box turtle stress levels differ by site and sex*
- *Comparison of urban and rural box turtles shows difference in body condition index*
- *Invasive snail feeding preferences may influence invasive and native plant composition*
- *Traits of an invasive Euonymus as compared to those of the local plant community*
- *Pollen limitation reduces reproductive fitness of some exotic plant species*
- *Examining the enemy release hypothesis in Ozark woody species*

Eastern chipmunk, Tamias striatus

Washington University in St. Louis

For more information:

Kim Medley, Interim Director
Tyson Research Center
6750 Tyson Valley Road
Eureka, MO 63025

email: kim.medley@wustl.edu
web: tyson.wustl.edu
phone: 314-935-8448
fax: 314-935-8433

Spotted salamander, Ambystoma maculatum