UMBS Research Experiences for Undergraduates
"Climate Change in the Great Lakes Region"
Projects 2021

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UMBS forest ecosystem study

Chris Gough, Virginia Commonwealth University and Chris Vogel, University of Michigan

Forests of northern Michigan provide several essential ecosystem services, including climate regulation through the sequestration of carbon dioxide. Our collaborative team conducts research on the scientific underpinnings of forest carbon sequestration, with a particular emphasis on how disturbance, canopy structure and composition, and age affect the capacity of the region's forests to sequester carbon.

We conduct this research in a variety of settings, including a 20-year experimental forest with a long-running carbon "flux" tower, two landscape-scale experimental disturbances in which >10,000 trees were stem girdled, a pair of long-term chronosequences with stands from 20 to >200 years old, and an experimental manipulation of disturbance severity in which tree mortality ranges from 45 to 85 %.

REU collaborators on the UMBS Forest Ecosystem Study team have numerous research options. Some examples include: 1) disturbance, climate, and forest age effects on carbon cycling; 2) mechanisms supporting carbon sequestration stability following disturbance; and 3) ecosystem structure-carbon cycling relationships.

From Forests to Space: using tree-based measurements to shed new light on NASA observations

Ashley M. Matheny, University of Texas at Austin

Carbon uptake and water use by forests are inherently coupled through the process of transpiration. As plants take in carbon dioxide from the atmosphere for photosynthesis, they release water vapor. Plants perform a delicate balancing act between having enough carbon to survive and not losing so much water that they risk drying out. Because forests couple the carbon and water cycles, it is critical that we monitor forest health and responses to disturbance and drought, the frequencies of which are predicted to increase as a result of climate change. NASA has developed several new sensing technologies to analyze forest water content from space through a product called Vegetation Optical Depth (VOD). However, we lack sufficient ground-based measurements to utilize VOD data to the best of our abilities. In this project, we seek an undergraduate researcher to help improve our understanding of how NASA's VOD product can be used to predict drought and even fire potential.

REUs students can contribute to our mission through assisting in a field campaign to collect water content data from leaves of multiple tree species at different times of day. VOD observations integrate water content from the top of the canopy down through the top soil layers. The REU student will combine their leaf-level data with observations of wood water content, soil water content, and canopy structure in order to help the partition VOD observations into each component (leaves, wood, and soil). These partitioned observations will help scientist and forest managers better understand how to use VOD data to predict forest health, disturbance, and fire ignition potential.

Songbird distributions and species interactions in a changing climate

Jason Tallant, UMBS, Dave Karowe, Western Michigan University, and Jordan Price, St. Mary's College of Maryland

Climate change will result in altered geographic ranges as species redistribute themselves across the landscape. Although birds are highly mobile species, their dispersal will be constrained by the slower movement of less mobile species, such as the plants of their preferred habitats. Variable dispersal abilities among species will result in new ecological communities, leading to new interactions among species.

The Audubon Society recently published a report containing detailed predictions of future suitable habitat, and therefore future geographic range, for hundreds of North American bird species (Survival by Degrees: 389 Bird Species on the Brink; https://www.audubon.org/climate/survivalbydegrees). An REU student could download the data files used for this report and generate detailed maps of future geographic ranges of several ecologically similar species (for instance woodpeckers). These maps could then be used to calculate change in range overlap between pairs of species, which can be used to infer potential future changes in interactions such as competition among North American bird species. Field work could be included to evaluate and compare the plant communities that comprise current suitable habitat for bird species of interest.
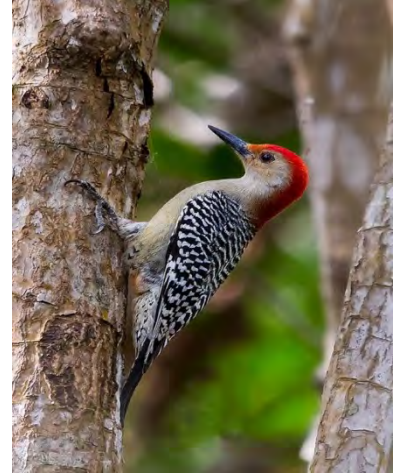
Interaction of stream flow and benthic organisms

Paul Moore, Bowling Green State University

Stream flow is the primary abiotic factor influencing stream ecosystem function. Physical forces associated with the flow can affect in-stream organisms such as crayfish and macroinvertebrates. However, natural systems have increasingly been under siege through flow alterations in the form of dams, land use, and extreme precipitation events (storms and droughts) due to climate change. An understanding of the direct and indirect pervasive effects associated with the natural flow regime is crucial to identifying and predicting responses of organisms (and by extension ecosystem processes) to flow alterations. How organisms respond to flow can also enhance our interpretation of any evolutionary adaptations to flow. All of this is vastly important when we consider human influence on natural systems in the context of global climate change.

My lab takes a broad approach to aquatic ecology in lakes and streams. We have done projects on predator-prey interactions with bass and crayfish, social behavior in crayfish, ecotoxicology in flowing and stagnant systems, and aquatic habitat restoration. Students working with the lab will get the chance to design projects on a variety of areas addressing the effects of climate change on aquatic ecology. For instance, an REU student could conduct an in-depth examination of the response of benthic organisms (e.g. caddisflies, mayflies, and stoneflies) and/or crayfish to changes in stream flow regime (velocity, magnitude or rate of change, drought, etc.).

Climate-induced forest disturbance and biogenic volatile organic compounds

Steve Bertman, Western Michigan University

The forests of northern Michigan have undergone much change in the last 100 years. Currently regrowing from widespread clearcutting, they are strongly affected by the changing climate. Future species distribution will depend on how temperature and soil moisture change in the next several decades, and emissions of biogenic volatile organic compounds (BVOC) into the atmosphere will depend on species distribution. BVOC drive the atmospheric chemistry that determines the composition of the atmosphere near the earth's surface. For example, production of tropospheric ozone, a potent greenhouse gas, is strongly affected by the amount and the mixture of BVOC emitted into the atmosphere. Surveys of white pine saplings in the UMBS forests have determined that intermediate forest disturbance influences the physiological response of BVOC production. The limited range of disturbance currently available hampers the strength of conclusions that can be drawn.

Global atmospheric change and carnivorous plants

Dave Karowe, Western Michigan University

Fossil fuel burning results in emissions of nitrogen-containing gasses into the atmosphere, and this nitrogen eventually returns to the land surface.

Depending on the emissions scenario we follow during the 21st century, nitrogen deposition from the atmosphere could increase or decrease. Carnivorous plants, such as pitcher plants and sundews, use their leaves to capture both carbon and nitrogen. However, they experience a trade-off between these two goals, since green tissue is best for photosynthesis but red tissue is best for prey attraction. An REU student could determine whether, in response to altered availability of atmospheric nitrogen, carnivorous plants are able to adjust their investment in nitrogen capture traits vs. carbon capture traits. For instance, an REU student could design a study to ask whether pitcher plants alter the ratio of red to green leaf tissue when exposed to future higher amounts of atmospheric nitrogen deposition.

Effects of climate-induced changes in streamflow on algal communities

Bob Pillsbury, University of Wisconsin-Oshkosh, Dave Karowe, Western Michigan University, and Paul Moore, Bowling Green State University

Algae that attach themselves to solid substrates such as rocks and woody debris (benthic algae) are the base of the food chain in many temperate streams. Streamflow - the velocity and turbulence of water flowing in these ecosystems - is a primary factor shaping benthic algal communities. Streamflow regimes are already being affected by anthropogenic climate change. In the future, climate change is very likely to result in further increases in the frequency and severity of extreme precipitation events, and therefore extreme streamflow events. Increasing periods of both high and low flows may have dramatic effects on the community composition of benthic algae. An REU student could use the UMBS Stream Lab to experimentally expose native algal communities to altered streamflow answer questions about changes to algal species, genera, and communities. For instance, do certain species benefit from increased high flow periods? Increased low flow periods? Are there morphological or phylogenetic characteristics that predict species responses to altered flow regimes?

The synergistic effect of climate change and invasive species on shifts in lake productivity

Rex Lowe, Faculty Emeritus, BGSU
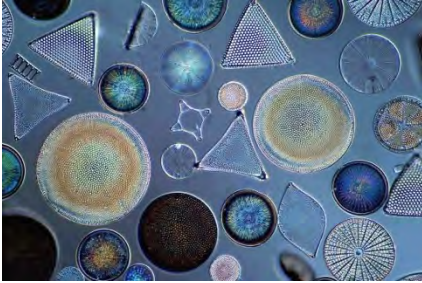
Models suggest that temperate lakes will continue to warm resulting in longer ice free periods. Records on Douglas lake indicate that the lake is freezing later in the fall or early winter and thawing earlier in the spring. This potentially results in longer days of light penetration into the water. In addition, the recent invasion of exotic plankivorous mussels has led to increased water clarity and the subsequent increase in the depth of light penetration in lakes expanding the area of lake littoral zones. In addition, as mussels expand with the capacity to drastically reduce quantities of phytoplankton we predict a shift in Lake carbon fixation from phytoplankton toward benthic algae. This process in the Laurentian Great Lakes has been called benthification of lake productivity. This phenomenon has been documented not only in the great lakes and others but more recently in large oligotrotrophic inland lakes such as torch lake in northern Michigan. In 1988 we analyzed the contributions of benthic algae and planktonic algae to whole lake carbon fixation in Douglas before exotic mussels had arrived. We now propose to repeat this research as the lake warms and as exotic muscles clear the water column. We hypothesize that benthic algae will now play an even greater role. We also propose to conduct a multi-lake survey in northern Michigan to determine the extent of littoral zone area in each lake. In Douglas Lake we will measure benthic and pelagic algal primary productivity employing light and dark chambers to measure carbon vaccination rates. The measurements will be done several times over the course of the summer. This research has ramifications on paths of the food web in lakes as the pelagic food web decreases and the benthic-based food web becomes more important.

Forests, climate change and carbon management

Luke Nave, University of Michigan

Forests remove carbon from the atmosphere and sequester it in trees, soils, and other parts of the ecosystem, helping to mitigate atmospheric carbon dioxide pollution and climate change. The actions that society takes with regard to forests, which range from preservation, to forest management, to the creation of new or loss of existing forests, have a significant impact on the roles that forests play in carbon pollution, climate change mitigation, and many other ecosystem services, at all scales. My research projects, conducted in partnership with collaborators throughout Federal agencies, NGO's, and academia, all relate to issues of forests, carbon sequestration and climate change. These projects range from hands-on, field-based data collection in long-term forest plots at the Biological Station, to novel analyses of existing databases that can be accomplished anywhere with a web-connected computer. I seek to work with students pursuing studies in ecosystem science, management, environmental policy, or related fields, who wish to gain experience in all phases of the scientific enterprise. Students will have opportunities to design, conduct, interpret, and communicate research projects through close collaboration, with emphasis on concurrent mentoring, personal and professional growth through the pursuit of scientific inquiry.

Climate change and the ecology of damselflies

Jordan Price, St. Mary's College of Maryland

Climate change is likely to affect stream ecosystems in a variety of ways, including water temperature, flow rate, and vegetation composition. Dark-winged or Ebony Jewelwing damselflies (*Calopteryx maculata*), which develop as larvae in streams and live as adults at the land-water interface, are therefore likely to be affected as well. An REU student could investigate the effects of various stream parameters on damselfly morphology, behavior, and infections by gregarine parasites. This project would involve fieldwork, behavioral observations, damselfly collection, and analysis of parasite loads.

Predicting the effects of climate change on an important Michigan resource; Wild Rice.
Bob Pillsbury, University of Wisconsin-Oshkosh

A recent decline in wild rice (Zizania palustris L.) wetlands is cause for concern due to its importance as a food source, refuge for wildlife, and cultural history. Yet a basic understand of this plant and the habitat it creates is lacking. For instance, we do not know the extent negative impacts from waterfowl grazing on current reseeding efforts. This results in making wise management plans for this resource and its watershed difficult. Wild rice now faces a new threat in the form of climate change. Recent predictions call for the climate of Michigan to resemble conditions currently found in Arkansas by 2100, with droughts of longer duration, more days over 95 °F, and more severe storm events. Milder winters are also forecast which may not only benefit wild rice but also its competitors. This can lead to unstable conditions for rice wetlands that are hard to predict with our current level of knowledge. We proposed to deploy a series wild rice Seed Germinating Substrata (SGS), which are resistant to grazing, in similar wetlands and across a wide range of latitudes to simulate warming conditions predicted for Northern Michigan. Alongside each SGS will be placed frames with wild rice seeds similar in nature to the SGSs but these seeds will be exposed to grazing. Germination and growth rates will be compared among habitats to determine the likely outcome of climate change and waterfowl grazing which should lead to management plant to preserve this valuable resource.

Watershed hydrology at UMBS
Katy Hofmeister, Michigan Technological University

Water is an essential part of all ecosystems. It connects terrestrial and aquatic systems, carrying energy, nutrients, and pollutants from the landscape to streams, rivers, and lakes. Water availability, timing, movement, and chemistry can be influenced by a variety of factors operating at spatial scales that range from local (*e.g.,* forest stands) to global (*e.g.,* climate change) and short (*e.g.,* storm events) to long (*e.g.,* multi-year precipitation patterns) temporal scales. REU students have the opportunity to explore how disturbance (*e.g.,* forest harvest, climate change) influences groundwater, streams, and inland lakes. This work can take several directions and include investigating how changes in climate have influenced precipitation patterns and lake levels using long term precipitation, climate, streamflow and Douglas Lake level measurements. We can address questions related to whether inland lake levels are in a high or low cycle, what the primary drivers of water levels are, and if precipitation or air temperature patterns have changed as a result of climate change.

REU students will also have the opportunity to utilize a forest harvesting experiment to explore questions related to how ground and surface water availability and movement respond to landscape disturbances. We can take soil, ground, and surface water samples across a gradient of forest management activities to explore the spatial patterns of water availability and chemistry. We can explore how land cover influences ground and surface water responses after small and large precipitation events. If students are interested, there is also the opportunity to explore the interactions between forest carbon and water movement. REU students can use their results to predict how climate change, by altering hydrologic regimes, might impact water in terrestrial and aquatic landscapes.

Effects of climate-induced forest disturbance on insect communities

Brian Scholtens, College of Charleston and Dave Karowe, Western Michigan University

Temperate forests are likely to experience more and stronger disturbances due to future climate change. For instance, droughts, increased pest populations, and increased pathogen outbreaks may result in substantial mortality of some tree species. The FASET (Forest Accelerated Succession ExperimenT) at UMBS mimics these types of disturbances; approximately a decade ago, over 7,000 aspen and birch trees were selectively girdled and subsequently died within the 40-hectare experiment. Twenty subplots have been monitored closely since girdling, and represent a wide range of disturbance severity (depending on how many aspen and birch trees they initially contained). This allows researchers to ask how disturbance severity affects many other aspects of forest ecology. For instance, an REU student could design a study to determine whether climate-induced forest disturbance alters insect communities (flying, ground dwelling, or both), which physical changes in disturbed forests have the greatest impact (light, temperature, etc), and whether disturbance particularly benefits invasive species.

DIRT at UMBS: Plants, microbes, and soil interact in incredible ways

Aimée Classen, University of Michigan and John Den Uyl, University of Michigan

Globally, soil contains more carbon than the atmosphere and all living biota combined. A large fraction of this carbon is stored in the form of soil organic matter (SOM), which consists primarily of decomposing plant and animal tissues such as roots and leaves, and soil microorganisms including bacteria and fungi. While we understand these things are connected, how they are connected is less understood because it's difficult to peer into the soil. The role soils can play in sequestering carbon from the atmosphere makes understanding these processes key to being able to accurately predict the impact of this potential carbon sink on future climate.

The Detrital Input and Removal Treatments (DIRT) were established at UMBS in 2004 to investigate how varying inputs, in the form of roots, wood, and leaf litter, contribute to the formation, degradation, and stability of soil. After more than 15 years maintaining these experimental manipulations, DIRT enables researchers the ability to 'peer' into soils and explore important processes. Measuring root growth and decomposition in these experimental plots is a critical component of these research goals. REU collaborators involved in our field and lab work will conduct guided research and gain fundamental skills in field-based ecological research and ecosystem science, relevant to careers in research, education, and resource management.

Utilizing the UMBS Burn Chronosequence to investigate microbial contributions to plant growth
    Aimée Classen, University of Michigan and John Den Uyl, University of Michigan

Microorganisms play a large role in a plant's ability to function and grow. The presence of specific microbes within the soil microbiome may positively, negatively, or neutrally affect a plants ability to uptake water, nutrients, and/or resist or tolerate plant pathogens. This relationship between plants and soil microorganisms has wide ranging implications towards understanding and predicting plant species distributions, soil microbial community structure, and the ability of an ecosystem to function under future environmental stressors or disturbances, most notably climate change.

Utilizing soils collected at the Burn Chronosequence, or "Burn Plots," at UMBS, we will investigate how these microbial communities affect plant growth through successional time. Large forested plots within the Burn Chronosequence have been burned experimentally by UMBS researchers nearly every 10-20 years for almost 100 years, resetting the successional clock of the forest with each burn and leaving researchers with a range of disturbed sites to study. As an REU student researcher on this project, you can harness this successional "time machine" to investigate how microbial communities in these disturbed soils differentially impact controlled plant growth with successional age. By growing plants in a greenhouse setting, we seek to compare how sterilizing these soils, thus killing all soil microorganisms, affects plant growth against non-sterilized soil that have microorganismal communities intact.

Dead Wood: where is it and how is it important
    Aimée Classen, University of Michigan and John Den Uyl, University of Michigan

Wood decomposition is an integral part of the global carbon cycle, yet the mechanisms that control decay rates are still relatively difficult to predict. Decomposition rates can be highly variable across time and space and are dependent on a range of diverse factors including climate, microbial community structure, wood species and quality, as well as interactions with insects and other macroinvertebrate communities. Climate change will affect these processes in unknown ways. New sensor technologies along with an increased understanding and emphasis on the importance of woody debris decomposition in forests has brought about many novel and exciting research questions. Characterizing fungal communities and measuring climatic conditions and at multiple spatial scales is of particular interest to our research group. The forests surrounding UMBS afford an REU student researcher a wealth of opportunities to study the many factors influencing wood decomposition and the impact it can have on carbon storage in Michigan forests. In coordination with extensive existing research datasets and infrastructure, this project will contribute towards a more comprehensive understanding of ecological processes occurring within the UMBS forest ecosystems.

Mapping forest and ecosystem structure using remote sensing to understand climate change impacts on Great Lakes forests
   Jeff Atkins, Virginia Commonwealth University and Jason Tallant, UMBS
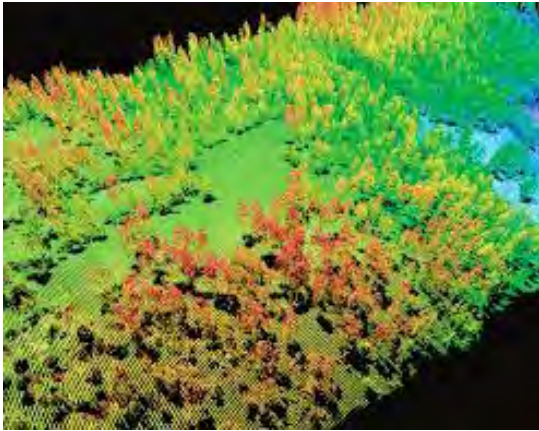
Climate change is directly affecting the forests of the Great Lakes region, potentially endangering the numerous ecosystem services these forests provide, including nutrient retention, carbon sequestration, habitat provisioning, water quality regulation, and biodiversity maintenance. Our collaborative team uses a combination of field and remote sensing data to address how climate change is impacting Great Lake forests with a focus on ecosystem disturbance, biodiversity, forest structure, landscape patterns, and ecological memory/material legacies.

We are specifically looking for REU student collaborators to work with data from the 2019 National Ecological Observatory Network (NEON) flyover of UMBS. These data include lidar, hyperspectral, and orthoimagery, all at the sub-meter scale and all that can be used singularly or in combination to map ecosystem structure. There is potential for interaction with project collaborators from multiple organizations including UMBS, Virginia Commonwealth University, University of Michigan, Michigan State University as well as Brookhaven National Laboratory and the US Forest Service. REU student collaborators on this project will have numerous research options. Some examples include: 1) tree crown delineation and species identification/mapping; 2) connecting remotely sensed data to specific ecosystem services of interest including within existing UMBS experiments and disturbance treatments; 3) mapping structure across UMBS to create foundational information to support future inquiry.