Transforming Student Learning Through a Sustainability Region Model
NSF Grant Proposal: Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics
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Project Summary

To significantly enhance pedagogy in the interdisciplinary study of the environment, we propose a sustainability region encompassing Ohio Wesleyan University and Delaware, Ohio, including long term plans for a network of research action locations linked by a pedagogical green trail. The action locations will consist of diverse environmental data monitoring and research projects, designed to immerse students in the scientific method and help them investigate real, complex problems related to local environmental issues and sustainability. These student research projects will be incorporated into a larger plan to understand the functioning of Delaware, Ohio as an urban ecosystem and to develop a regional sustainability plan. We will partner with the City of Delaware to integrate data collected by the City (e.g., water quality sampling, waste and sewage volumes, etc.) and the Ohio Wesleyan physical plant (e.g., building energy, water use, etc.) with data from student research projects in a central online location. A part-time Student Sustainability Research Coordinator will serve as a liaison to the City and manage the central database, assist students and faculty in the development of student projects that address local needs, and use these data to develop a regional sustainability plan. Our project will enhance the understanding of the scientific method by non-science majors and the understanding of social factors in environmental problems by natural science majors. It will allow students to more easily pursue long-term projects that build on past student research and take advantage of lessons learned. Finally, it will ensure substantive theory-into-practice research experiences for our students that contribute to significant improvements in long-term regional sustainability for the Delaware community.

The **intellectual merit** of this project is that it enhances the understanding of the scientific research process by students in the natural and social sciences by immersing them in tangible, real-world projects that engage them with professionals (on and off campus), and enables them to contribute to a broader understanding of the regional ecosystem. Students will learn how the scientific process applies to study of the environment and to the emerging field of sustainability. As sustainability issues involve both natural and human factors, our project involves integrating human impacts within the study of ecosystems and habitats. Students will shift from seeing humans as separated from the natural world to being fundamental players in its processes. Students will also appreciate and embrace the complex partnership between the natural and social sciences that must occur in order to enact meaningful changes in sustainability. The **broader impacts** of this project are embedded in the university partnership with local community leaders and citizens. Data from our project will have the potential to inform local environmental policy, support local efforts for environmental improvements, and educate citizens about the biodiversity and ecosystem processes happening in their own backyards. Local elected officials are enthusiastic supporters of this project and we look forward to working with these partners in the living laboratory of our surrounding community. We also see our model as one that can be expanded and adopted by other campuses and their communities. The eventual development of a network of such sustainability region projects would allow for interaction, learning, collaboration, and development of the core ideas in the project over regional to national scales.

Project Description

I. Project Motivation and Pedagogical Innovation

Many idealistic young adults want to make a positive difference in the world and many are concerned about human impacts on the natural environment. In 2011, 68% of high school students surveyed by the Princeton Review indicated that a college's commitment to environmental issues would figure at least somewhat in their college selection process (Princeton Review 2011). Traditionally, undergraduate education has provided the background knowledge and critical and integrative thinking skills necessary for graduates to tackle complex problems such as those involving human effects on the environment. However, much of this education has been delivered through traditional lecture and readings, providing few opportunities for students to immerse themselves in the process of investigating and addressing environmental problems. Increasingly, experiential learning and student-initiated projects are emerging on college campuses (a positive development in our opinion, e.g., Moore & Fitchett 2004). In accordance with this trend, and building on new curricular initiatives at Ohio Wesleyan University (OWU) that combine a globally focused curriculum with off-campus learning and leadership opportunities that translate classroom theory into real-world practice, our proposed project develops a series of diverse, interconnected, student research projects that will occur in classes and independent studies, and contribute to a broad, regional environmental sustainability plan. Our proposed project links undergraduate interest in the environment to the scientific research process in a real-world, long term initiative with diverse practical impacts in our community. PI Krygier has engaged in individual projects on environmental problems with students over the past decade, including projects that have resulted in peer-reviewed publications (Hawthorne, Krygier & Kwan 2008). The goal of this proposal is to synthesize these individual efforts into a coordinated, long-term student research program focused a spatially defined sustainability region, and involving a broader range of students and faculty from the social and natural sciences. We believe that placing student projects in the sustainability region context will lead to enhanced educational experiences for students and improvements in community sustainability.

Our project's target audience is students majoring in Environmental Studies at OWU. The Environmental Studies (ES) major at OWU is a magnet for students with interests in the environment. The major requires a second, traditional major. Half our ES majors have a second major in the natural sciences, and half in the social sciences. All ES majors must complete an independent research project focused on an environmental topic. While we believe these projects have value, we have found that the work is often confined to disciplinary silos, with little coordination among projects and classes. Students engage enthusiastically in their projects at first, anxious to "make a difference," then find that they failed to understand the complex and multidisciplinary nature of the issues they were exploring. Natural science majors may succeed in collecting data describing an environmental issue, only to find an unexpected barrier to enacting change, such as lack of money, adherence to tradition, or a pattern of human behavior. Social science majors often grasp the social or economic context of an environmental issue, but fail to collect the robust data needed to convince those in positions of authority of the scope and gravity of the problem. Both groups of students are strongly motivated to address environmental issues, but end up needing tools from other disciplines to enact meaningful change.

We also see a significant drawback to our current approach to the ES research project, even with the most successful projects. The student makes reasonable progress researching an

issue, but the project ceases at the end of the semester. Many student projects address longer-term issues that require more than one semester of work to produce real change. Such relatively short-term projects on longer-term issues lead to frustration for students and, when faculty memory or communication fails, constant "restarts" of student-initiated projects on topics ranging from composting to local food in the dining halls to analysis of utility usage in campus buildings. Part of our requested funding will support the development of a database that stores project data and outcomes in a common, easily accessible online location with powerful visualization tools, enabling students to build upon previous research by their peers.

To address the current shortcomings of our program, we have developed a pedagogically innovative approach focused on the ideas of a sustainability region, action locations and a green action trail enabling coordinated and integrated student research on environmental problems in the community surrounding OWU. Delaware, Ohio is a town of 30,000 residents in a landscape of rapid suburban development (Delaware is 30 miles north of Columbus) integrated with agricultural fields. Delaware County is among the most rapidly growing counties in the United States over the past decade (US Bureau of the Census), and so is experiencing intense land-use change, along with typical problems such as pollution, urban air quality degradation, and an increasing carbon footprint. While our campus has its own unique ecological footprint, we are interested in having our students view OWU's environmental impact in the context of the broader community, and having their research address problems beyond the campus borders.

A key requirement for developing student projects that make substantive contributions to environmental issues on campus and in the City of Delaware is having a Student Sustainability Research Coordinator (SSRC). This coordinator will serve as a liaison to the City and campus community, assisting students and faculty in identifying projects that address pedagogical goals while serving local environmental needs. The SSRC will have experience in sustainability planning and will integrate student project data and outcomes into a long-term sustainability plan for the campus and broader community. Our funding request includes support for a part-time SSRC position that would manage the sustainability region database, work with the University and City to identify environmental priorities appropriate for student research, work with students and faculty on project design, and use these data as the basis for a long-term regional sustainability plan. We feel this position is vital to transforming our students' work from purely pedagogical exercises to useful contributions to the campus and community.

There are pedagogical and intellectual advantages to the sustainability region approach. Students have easy access to a "laboratory" within walking distance of campus. Students approach the concepts of "ecology" and "ecosystem" with humans fully embedded in the study of environmental issues, and environment fully embedded in the study of social issues. This approach is influenced by the concepts of *anthropogenic biomes* (the integration of human and environmental factors within the concept of the biome, Ellis & Ramankutty 2008), *reconciliation ecology* (seeking biodiversity in human-dominated environments, Rosenzweig 2003), *political ecology* (analysis of social, political and economic characteristics of ecological phenomena, Robbins 2005), and the *human ecosystem model* (the application of ecosystem interactions to human-dominated systems, Pickett et al. 2011). Finally, students can make important contributions to the community as they focus their intellectual abilities, labor, and creativity on real problems that have the potential for significant, long-term positive change. This approach resonates with OWU's long tradition of student service: OWU earned a 2009 Presidential Award for Excellence in General Community Service and is featured in the book "Colleges That Change Lives."

II. Student Learning Goals

Our proposed project engages students in diverse majors in the natural and social sciences. It encompasses a broad range of specific studies of diverse components of the sustainability region. Each student project, guided collaboratively with faculty and the SSRC, will include the following student learning goals:

1. Engagement in the scientific process through at least one and ideally all of the following: hypothesis formulation and testing, data collection, data analysis and evaluation of evidence, preparation of data for external communication, and dissemination of data to a wider audience. Students will investigate real environmental issues in the community, such that these projects will be authentic research experiences, not just pedagogical exercises.

2. A study of the social science context and implications of the problem under investigation, and an analysis of how the data assembled will lead to recommendations for action that are appropriate in the social science context of Delaware, Ohio.

3. Application and relevance to the over-arching goals of (1) increasing our understanding of Delaware, Ohio as an urban ecosystem, and (2) enhancing the environmental sustainability of this community.

These components represent best practices in STEM education as described in the *Vision and Change in Undergraduate Biology Education* report (Brewer and Smith 2009). Specifically, this report calls for greater emphasis on learning science by engaging directly in the scientific process (rather than listening to lectures, for example) and notes the importance of students studying core competencies using relevant topics (such as environmental sustainability). In addition, the report emphasizes exploration of the connections among different academic disciplines and understanding of the relationship between science and society. Finally, the report calls for transformational education in the sciences to be available to all students, not just those who major in science. The proposed project represents a significant enhancement of Ohio Wesleyan's already interdisciplinary Environmental Studies Program by bringing environmental research opportunities to a broader range of students, linking those research opportunities in an intentional way to community issues, and providing continuity among student projects over time to bring real, long-term change to the sustainability region.

III. Scholarly Context: The Sustainability Region and Anthromes

Our sustainability region includes the urban, suburban, and rural agricultural landscapes of Delaware, Ohio spanning a variety of human and natural environments. We envision the sustainability region as a long-term organizing concept for a wide range of student projects related to sustainability and the environment. However, these projects can be grouped under broad themes central to the study of urban ecosystems, similar to those examined in the Baltimore Ecosystem Study (Pickett et al. 2008) and those that underpin the human ecosystem model for urban systems (Pickett et al. 2011). Building on these themes, students will work toward the following long-term goals through various focused studies:

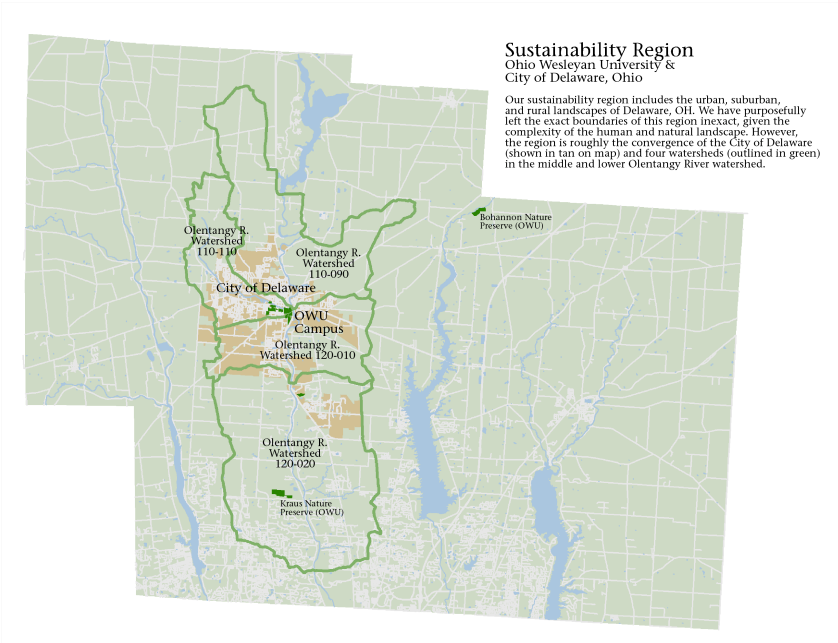
1. Describing the biological, physical, social, and built components of the Delaware, OH environment and understanding how these influence each other.

2. Describing and understanding the fluxes of energy, materials, and organisms (including humans) into and out of Delaware, changes in the local built and economic/social environment, and how these interact and vary over time.

3. Using this information to improve the long-term environmental sustainability, responsibility, and quality of life for the Delaware, OH community.

As noted above, these themes are not novel in urban ecology, but to our knowledge have never been the focus of systematic, long-term study in our community. The Delaware City government is attentive to environmental issues in the town as regulations require, but like many small cities, lacks the resources for comprehensive studies of local interactions among human and natural components of the urban system. We believe that the synthesis of existing data and generation of new data about our local environment through student projects will provide an excellent information resource to the city that can be used to justify initiatives, target scarce resources, and facilitate environmental planning, while giving our students invaluable real world experience.

We have developed preliminary boundaries for our sustainability region, and will continue to evaluate these boundaries as the project progresses. Defining ecoregions is complex and difficult, yet vital: ecoregions "provide a holistic spatial framework that helps promote understanding of ecological processes and phenomena. This understanding, in turn, helps people describe, evaluate, and manage ecoregions" (Olstad 2012, p. 307). Initially, the region is defined as the convergence of the City of Delaware boundaries and four watersheds in the middle and lower Olentangy River watershed. Thus the region is defined by both political and natural boundaries (Map 1).

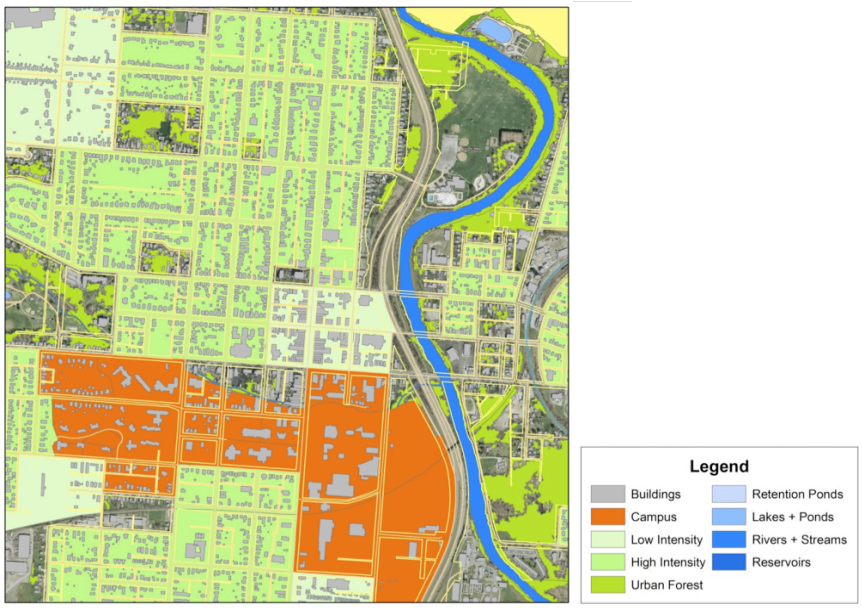


Map 1: Sustainability Region

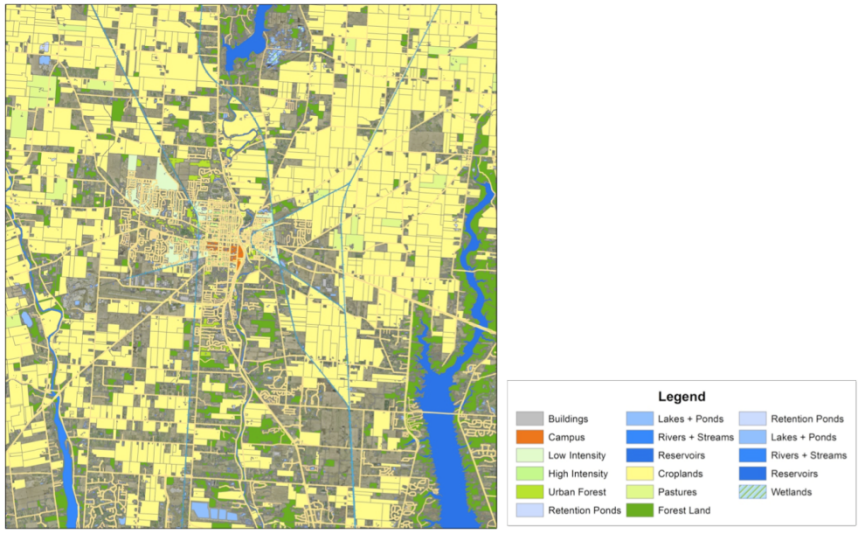
Over the past two years, two student projects have examined the concept of *anthropogenic biomes* in the context of our sustainability region. Such biomes include humans and human landscapes in addition to animals, plants, climate, and landforms, providing a useful synthesis of natural and social science perspectives (Ellis & Ramankutty 2008). A preliminary classification and mapping of anthropogenic biomes (shortened to *anthromes* by one of the student researchers) in the sustainability region included 7 habitat types: woodland, open woodland, grassland, open lawn, river/stream, lake/pond, and grey (urban) spaces. Student research during the spring of 2012 expanded and refined the biomes to more adequately incorporate human and urban characteristics of the sustainability region (Kusin & Reierson 2012). In particular, our classification combines ecological biomes with a diversity of human land use classifications. Our revised set of anthromes includes:

1) Built Up
   a) Urban
   b) Campus
   c) Backyard (high intensity, low intensity)
   d) Island
   e) Urban Forest
2) Agricultural
   a) Cropland
   b) Pasture
3) Natural Transition Zone
4) Forest Land
5) Natural Water
   a) River
   b) Lake
   c) Retention Pond
   d) Reservoir
6) Wetlands

Maps 2 and 3 show two areas of a preliminary mapping of the anthromes of our sustainability region. These maps were created from diverse existing data for the region, including data from the state EPA and the County Assessor's Office.



Map 2: Map of Anthromes in the Sustainability Region (OWU Campus and Downtown Delaware, Spring 2012).



Map 3: Map of Anthromes in the Sustainability Region (Spring 2012).

IV. Proposed Projects in the Sustainability Region

We seek funding in this proposal to establish the conceptual framework and database for the sustainability region, and to initiate and develop projects that will take place within it. We have chosen to start with projects (Phase I) that complement ongoing research by PIs Krygier and Anderson. These Phase I projects are of high priority and will be initiated at the start of the grant cycle, building on preliminary data already collected by students. Phase II projects are those that will be developed more fully during the grant cycle to diversify the work within the region and engage a greater range of faculty and students. These will be initiated after the first year of funding, with support for materials and supplies coming from other funding sources.

Phase I Projects

The Carbon Footprint of the Sustainability Region: The carbon cycle represents one of the most fundamental interactions between the built and natural environments and the social and natural sciences. Therefore, initial projects in the sustainability region will focus on characterizing the region's carbon footprint. Students enrolled in classes and independent studies with PI Krygier will focus on characterizing spatial and temporal patterns of energy use in the sustainability region. Students enrolled in classes and independent studies with PI Anderson will focus on characterizing carbon storage and fluxes from plants and soils, and mapping ground-level atmospheric CO_2 concentrations throughout the region. Both PIs and their students will be supported by the SSRC, who will assist in integrating utility and urban forest data from the City with data collected by students in the central database, identifying specific areas of focus in this work in collaboration with city and campus utility managers, and integrating findings into a regional sustainability plan.

A. Building energy use in the sustainability region: Major buildings are an important source of human energy use in the sustainability region. Students, faculty, and community members spend a significant amount of time in the controlled environments of buildings, and the quality and

quantity of their activities in those buildings determine the amount of energy used. In turn, such energy use has a profound impact on both the local and regional environment. We propose a network of building energy monitors feeding directly into our sustainability region database, allowing access to both real-time and historical energy use data for major buildings on campus and in the City of Delaware. A map-based interface, data analysis tools (data classification, animation of data over time, etc.) and data options (total numbers as well as data "normalized" to take into account variations in building size and usage allowing for more accurate building by building comparisons) will be included in our database. The information will be used in diverse research projects. For example, students may develop an energy saving strategy for one or several buildings by examining existing energy use data documented by the monitors. Students will access data on energy usage before and after their intervention to assess the impact of their strategy (Vanichstian & Wood 2012). Successful strategies can be spread to other buildings (and also assessed). Less successful strategies can be modified and retried or abandoned. Our building-based energy data can also be used to guide strategic interventions focusing on those buildings that are the least efficient in their energy usage. Research can also focus on correlations between energy building usage and weather and climate patterns, carbon footprint data (see below), and variations in the human use of different buildings. Besides offering diverse and meaningful research opportunities, building-scale energy monitoring allows individuals to more readily comprehend the manner in which their particular actions and activities in particular buildings affect energy usage. An individual participating in an energy reduction strategy in a particular building can see the actual effects of their action, which is more likely to reinforce and sustain such sustainable energy practices (Jolliff, Pinkerton, Rux, Tice & Varner 2012).

B. Carbon sources and sinks in the urban ecosystem: The contributions of vegetation and soils to carbon storage and fluxes in the urban ecosystem of Delaware, Ohio have never been quantified, to our knowledge. PI Anderson will engage students in her upper level ecology classes (*Plant Communities and Ecosystems* and *Global Change Biology*, both electives for the ES major) and students doing independent research for ES, in projects measuring the amount of carbon stored in urban vegetation over time, carbon fluxes from soil, and ground-level atmospheric carbon dioxide throughout the region to identify "hot spots" of carbon dioxide release. Specific research questions that could be pursued include:

1. What are the carbon stores and fluxes in specific anthromes within the sustainability region and how does land-use change affect carbon storage and fluxes?

2. Where and at what times in the sustainability region do we detect the greatest changes and densities in atmospheric carbon dioxide levels and how does this connect with the distribution of anthromes and human patterns of transportation and energy use?

3. How do carbon storage and fluxes within the urban ecosystem compare to those in Ohio Wesleyan's two forested nature preserves?

In Dr. Anderson's upper level classes, lab and/or class sessions will be devoted to training students in equipment, techniques and concepts. Carbon contained in vegetation, particularly trees, will be assessed using repeated measurements of diameter at breast height (dbh) using diameter tapes or dendrometer bands (on selected trees). The dbh measurements will

be used to estimate tree biomass using conversion equations such as those in Jenkins et al. (2003) and Wharton et al. (1997). Photosynthetic measurements on vegetation will be conducted with the LI-6400 infrared gas exchange system (LI-COR Biosciences, Lincoln, NE) in PI Anderson's lab. Soil fluxes and ground level atmospheric CO_2 concentrations will be monitored at selected locations using the LEEF Carbon Monitoring System (LI-COR Biosciences, Lincoln, NE). PI Anderson has extensive experience measuring gas exchange with LI-COR instrumentation (Anderson et al. 2001, Gill et al. 2002, Anderson et al. 2010). All campus trees greater than 5 cm dbh (n = 1,834, 105 species) have already been mapped and their dbh measured in student independent study projects with PI Anderson and OWU faculty member D. Johnson (Graver 2009, Stull 2009). PI Anderson is also in the process of establishing permanent plots in the OWU nature preserves for long-term monitoring of carbon storage in trees as part of another project. Therefore, the proposed studies have solid foundations and points of comparison for future work.

Students in PI Anderson's class will consult with the SSRC to develop their project ideas (see below) and then carry out group or independent projects on carbon flux and storage topics over the course of the semester, as appropriate for the class. Data from the projects will be uploaded to the proposed central database at the conclusion of the study, and student learning from the project will be assessed as described below.

Funding is requested to purchase a LEEF Carbon Monitoring System through the LI-COR Biosciences LEEF Matching Funds program (see attached award letter), dendrometer bands for long-term monitoring of urban tree growth, and weather stations for the campus, city, and nature preserves since carbon fluxes are tightly linked to local weather and climate.

Phase II Projects: We propose to develop Phase II projects more fully during the funding cycle with the input of the SSRC and interested faculty, students, and city personnel. Project supplies will be sought through the Ohio Wesleyan Theory-into-Practice grant program or other funding sources. Initial student research on most of the Phase II projects has taken place during the 2011-12 academic year. We include brief descriptions of these projects because the requested funding from NSF will support project development and data from these projects will be integrated into the proposed central database.

Water quality monitoring: This study will assess the quality and characteristics of water in the sustainability region. Our focus will be on the Delaware Run (a stream adjacent to campus) and retention ponds located on campus and near recent commercial developments. The water quality challenges (run-off of pesticides, industrial chemicals, pollutants from parking lots) and habitat potential of these sites will be explored and monitored. Data will be accessed from Delaware drinking water and well water monitoring for comparison. A new water plant has recently been installed in Delaware and data from this plant will also be included in the project (Fesz 2012).

Biodiversity in the urban ecosystem: Our long-term goal is to compile a complete species list for the sustainability region and monitor urban biodiversity over time with periodic surveys and student collections. Biology classes at OWU already do plant, insect, fish and bird surveys; the SSRC will work with the faculty in these classes to systematize their data collection for long-term monitoring and uploading the central database.

Feral cat monitoring: Delaware contains significant populations of feral cat colonies that may play a significant ecological role in the sustainability region. The SSRC will explore options for

studies of these animals with faculty and city animal control personnel, with potential plans for tracking individual animals, studying their impact on the sustainability region ecosystem, and relating animal ethics issues to the biological studies (based on the interest of Environmental Studies and Philosophy faculty member Shari Stone-Mediatore, Titus 2012).

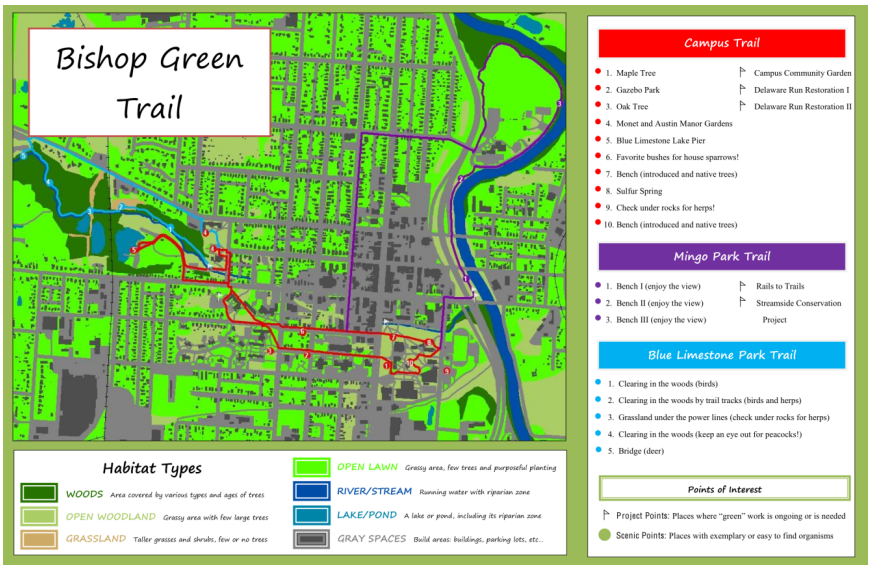
Invasive plant monitoring: This project will involve the identification of invasive plants and estimates of their population growth in campus and public urban habitats. Removal of plants will be studied to compare effectiveness of different methods within different anthromes. Students will engage in long term monitoring of populations as appropriate. PI Anderson has an independent study student working during 2012-2013 to collect preliminary data for this project.

Green business: The "green" efforts of businesses in the sustainability region and the availability of green products and services will be assessed through comprehensive survey methods. The project can be expanded to non-business offices (city government, agencies, campus offices, etc.). The survey will tie into GIS coordinates for the region so that locations of green businesses can be documented, and the long term success and activity of green businesses will be monitored. A survey mechanism, data collection methods, and informational materials have been created and are being reviewed by city business leaders (Car & Kiendl 2012).

Waste streams in the urban ecosystem: Monitoring the waste streams on campus (and eventually in Delaware) and assessing the impact of efforts to reduce and redirect waste to recycling, composting, and reuse are the focus of this project. We will map the actual waste streams, including quantities of recyclables, compostables, and garbage on campus, as waste moves from individual buildings to centralized collection. Data recording scales will be used to collect quantitative data on different categories of waste and map the data in our database (Callahan & Khalifa 2012).

Solar and wind energy on campus: This project centers on pedagogical solar and wind turbines with real-time data collection capacity to feed into our database. Students will use sensors on the weather station to document long-term patterns of sunny vs. overcast days and relation to solar energy potential. Demonstration solar panels and wind turbines will be installed where students can monitor energy creation and tap into it for applications (Rux 2011, Newman 2012).

Pedagogical green trail: With the anthromes in our sustainability region as a background, we propose to link together a series of research action sites and exemplary locations in our different anthromes with a pedagogical green trail (Map 4). The idea for the green trail was inspired by a similar trail at Mt. Holyoke College. We propose a marked trail system throughout the sustainability region, connecting environmental monitoring and research sites, distinctive ecological areas, green buildings and projects, sites of ecological reconciliation, and environmental engagement. The environmental monitoring sites are an important component of this trail, and will include sites with both human and natural focus for assessment of current status, change, and impacts of sustainable initiatives. The green trail will be used by OWU faculty and students for research, K-12 education, local citizens, and, potentially, "green" tourism (bike trails, bird watching, etc., Palmer & Bowes 2011).



Map 4: Map of Habitat Types & Proposed Green Trail (Spring 2011)

V. Online Database

Central to our proposed project is development of an open-source web-based database with analytical and mapping capabilities. The database will be a widely accessible location for the extensive, interacting datasets related to the sustainability region and is vital pedagogical "equipment" for the development of the region and associated sustainability plan, within which student research plays a central role. PI Krygier has extensive research and pedagogical experience in the area of cartography and GIS and is guiding the design of the database and visualization system (Krygier & Wood 2011). The lack of a comprehensive database is a fundamental hindrance to student research and learning for the following reasons:

1. Currently, student and faculty research project outcomes exist as papers or presentations in diverse formats, or as maps in particular software, in the possession of individual students and faculty. New projects are initiated without awareness of previous research; data and results from earlier projects are impossible to locate. Students graduate and their efforts are not preserved. Students seeking research ideas have no easy way to see the diversity of regional research projects that have been completed or are underway. They are not aware of data sources that could underpin research efforts.

2. Student and faculty researchers may be unaware of environmental research by city, county or regional professionals whose data and reports are often limited in distribution. Off-campus researchers are unaware of campus research projects.

3. Mapping (geographic information systems) and data visualization are increasingly important in research on the environment, energy, and sustainability, but there are limitations in mapping and analytical tools for regional scale areas. Available mapping tools tend to provide data at a scale that is too coarse for regional research. Jobs in the environment, energy, and sustainability fields increasingly require skills in mapping, GPS, and GIS.

We propose a web-based interactive map for our region linked to a database containing diverse spatially referenced data related to environment, energy, and sustainability. The system is based on "crowdsourcing" – an established form of collaborative information development. Users will explore and analyze existing data from a diversity of sources, brought together in the system. Users with an account can upload data and information to the system including PDF reports (linked to locations), data sets (linked to locations, or mapped out if the data contains geographic coordinates), images, sound (bird song, ambient noise monitoring), etc. The system will automatically import data from a proposed array of environmental monitoring sites (building utility monitors, weather, air and water monitoring, etc.). Users must develop adequate metadata for their contributions (including keywords, subject areas, temporal information, type of data, creator, etc.). Contributions will be reviewed for completeness prior to acceptance (Lee 2011).

Our proposed database greatly enhances student research skills by allowing the integration of diverse data and research outcomes in a centralized web location. It also enhances communication and engagement among students, faculty, and city, county and regional professionals and facilitates progress on regional issues related to the environment and sustainability by building on previous work. Finally, it allows for the mapping and visualization of data and information in a manner that will enhance understanding of the sustainability region and its diverse characteristics. Nothing like our proposed system exists (nor is there any off-the-shelf software that provides such functionality) despite a rapidly growing interest in sustainability, environment, and energy at a regional scale. Our project is based on open-source programming, allowing the software code and functionality to be shared with other academic and professional collaborators working on similar projects elsewhere. A significant part of our requested funding is devoted to the development of this database.

Students will learn to access the sustainability region database as part of the vital review of literature and previous research component of their projects. Students will engage with and analyze existing data incorporated in the database to generate research and project ideas. Students will learn to adequately format, organize, and share their research results. The general outcomes of the proposed project are an enhanced set of research skills vital for graduate and professional work. These skills will be learned by both natural and social science majors, are based on access to, creation and analysis of empirical data. The project offers exposure to and engagement with important technologies (databases, crowdsourcing, mapping) that play a key role in contemporary professional work in the environment, energy, and sustainability.

VI. Assessment of Student Learning Goals

Students who have completed a project in the sustainability region should:

1. Gain confidence and ability in applying the scientific method to actual problems in environmental science and sustainability.

2. Be able to describe the kinds of data needed to address particular issues and design an appropriate experiment to acquire these data.

3. Be able to describe the social science context of the issue under study, interconnections between social and environmental phenomena, and barriers to acting on scientific findings.

4. Be able to articulate how their project contributes to our understanding of the Delaware, OH urban ecosystem and/or regional sustainability.

5. Be able to recommend appropriate next steps for future student research and/or the Delaware community based on the findings of their project.

Student progress toward these goals will be assessed using a pre-test/post-test model in which students will answer questions related to the learning goals at the beginning and end of the project, using the sustainability region database interface for test administration. When students begin their project, they will be asked to establish a user account in the database and will answer pre-test questions during this set-up phase. Similarly, when students upload their final project, they will be asked post-test questions as part of project completion. The pre-tests and post-tests will be scored using a rubric method. We will work with Dr. Barbara Andereck, Associate Dean of Academic Affairs for Assessment and Accreditation and Interim Dean of Academic Affairs, who has extensive experience developing assessment tools with faculty at OWU, to develop the pre- and post-test questions and scoring rubric. User accounts will also track individual use of resources in the database, which will allow empirical study of frequency and intensity of use.

Students will also present their work during a series of lunch meetings and an annual poster session that includes members of the University and Delaware Community. Each lunch meeting will focus on a particular learning goal, and a rubric will be designed for faculty to assess student progress on these learning goals. These data will be used both as formative (for the student and the project) and summative data and the database will provide a means of including this data. Surveys will be conducted to gather anonymous feedback on the value of student projects from a community perspective. Participating students, faculty and community partners will also be surveyed each year about their perceptions of the value and logistics of the sustainability region. Assessment findings will be reviewed at an annual meeting of participants, and summaries of the results, and actions or changes based on the results, will be available on the project database web page. A student assistant will be hired to help the PIs process and summarize assessment data.

VII. Environmental Studies and Sustainability at Ohio Wesleyan: The Need for a Student Sustainability Research Coordinator

The faculty established Ohio Wesleyan's Environmental Studies program in 1979; it was the first degree of its type at any private college in Ohio. ES at OWU was envisioned as and continues to be a broad, cross-disciplinary approach to the environment, encompassing the natural and social sciences and humanities. The program consists of about 50 courses taught by 25 faculty throughout the university. There are no courses or faculty that are exclusively associated with ES. Instead, the program draws from courses and faculty housed in traditional departments on campus.

The ES Program at OWU has a long and respected history in the curriculum. Despite having no full-time faculty appointments and no budget, the program has managed to graduate on average 6 majors a year. The program currently has 20 majors, more than double the majors of any of the seven other interdisciplinary programs on campus. Over the last 9 years, there is nearly a 50/50 split of second majors between the natural and social sciences (46 natural science majors, 43 social science majors, 7 humanities, and 1 arts). These data suggest the program is appealing to students with diverse majors and is truly interdisciplinary.

A key component of ES, present in the program since its founding, is the requirement for an independent study credit. The goal of this requirement is to engage each ES major in an applied, "theory-into-practice" research project. This focus predated Ohio Wesleyan's recent emphasis on "theory into practice" across the disciplines by thirty years. This proposal is motivated partly by the desire to further enhance the applied project component of the ES program by hiring a SSRC. We recently hired campus Sustainability Coordinator Sean Kinghorn to develop a 10 year sustainability plan for the campus through a two-year grant, and he has assisted in a series of student projects on and around campus relevant to both his and student interests in the environment and sustainability. We have been impressed at how his contributions have helped student projects become more relevant and productive. Through collaboration with the Coordinator, students have already played an important role in shaping and structuring the broader project we propose, and their reactions, feedback, and contributions in two of PI Krygier's courses over the past two years are at the basis of this project. Student-faculty-Coordinator interactions in these courses define the future role the Coordinator would play in our proposed project and the relationship between the Coordinator and the co-PIs of this proposal. In Krygier's classes, the Sustainability Coordinator met with students during class time to hear student interests and ideas for projects related to the sustainability region, and also presented current projects he was working on. This "brainstorming" exercise allowed the Coordinator to relate his daily work to student interests, and to help students focus broad interests on a specific project in the region. Students then developed project proposals and these were critiqued by the faculty, Coordinator, and students. The course instructor and Coordinator arranged additional input from other faculty, staff, or off campus professionals as needed, and the students worked to complete the project over the course of the semester. A final presentation of the work was made to faculty, staff, the Coordinator, and other students. The collaborative work has had some important pedagogical impacts:

1. Social science, humanities, and arts students have come to learn and apply the scientific process of hypothesis formation, empirical data collection, and analysis. An empirically sound approach to a real-world problem serves as a vital means of formulating solutions (based on empirical data), assessing impacts and effecting change.

2. Natural science majors have come to understand and appreciate the social context of science in practice. A scientific solution to a real-world problem is only the first step in affecting change.

3. Students are more engaged in their projects and see them as part of a larger plan to affect change on the OWU Campus and surrounding community. These are not projects that conclude with the semester. Instead, these projects contribute directly to long-term sustainability.

4. Students are more engaged with professionals, such as campus staff (the Sustainability Coordinator, food service, buildings and grounds) and community professionals (city manager, environmental and health officials). Such engagement heightens the seriousness of the student's work and allows them to learn from professionals in their areas of interest beyond the faculty.

5. Faculty are empowered by the professional knowledge of non-academic professionals on and off campus. Student engagement requires faculty engagement, and faculty can learn how ideas and methods in the classroom can be effectively put in practice outside of the classroom. Indeed,

a key recommendation of the Association for Advancement of Sustainability in Higher Education for successful integration of sustainability into the curriculum is to bring faculty together with sustainability-oriented staff in collaborative educational projects (AASHE 2010).

6. The Sustainability Coordinator is able to make significantly more progress on campus and area sustainability projects given the engagement of knowledgeable faculty and students.

Given the presence of a Sustainability Coordinator and the positive impacts of collaborative work on sustainability, we seek to enhance the already existing independent study component of the ES program with a formal relationship between the Sustainability Coordinator, faculty, and students. All ES majors as well as interested non-majors will engage in STEM-oriented research to be integrated into the campus and region sustainability plan. To this end, we are requesting funds to cover a portion of staffing costs for this sustainability and student research coordinator. At this time, the Sustainability Coordinator position is supported by an external grant. NSF TUES funds will be used to support that portion of the Sustainability Coordinator's job devoted to work with students and faculty as outlined in this proposal. The timeline of NSF funds and the current external grant will not overlap.

VIII. Sustainability of the Proposed Project

We have designed the proposed project to be sustainable with a combination of university and external resources:

1. Students and faculty may apply for "theory into practice" grants from the University that can fund research projects related to the sustainability region. A student gains experience in grant writing as well as expending funds for research needs.

2. Students may apply for student assistantship positions (StAP Program) generated by faculty and staff at OWU. These are part-time paid positions, equivalent to a teaching or research assistantship, and may be used to fund student research in the sustainability region.

3. Students may apply for a Summer Science Research position. This program funds students and faculty for summer research projects, with can focus on sustainability. The budget includes a student stipend, living expenses, a faculty stipend, and an equipment budget for research.

4. The Environmental Studies Program at OWU is undergoing revision and enhancement in tandem with our proposed sustainability region project. We expect an external review of the ES program in Fall 2012 and will propose program revisions based on the recommendations of the review to faculty by Spring 2013. We view the sustainability region as an important organizing principle for our renewed program that has the potential to significantly strengthen and coordinate the diverse aspects of our curriculum. OWU is fortunate to have a number of alumni with a personal and/or professional commitment to environmental issues who are interested in the ES program and related environmental/sustainability initiatives. We anticipate approaching them for financial and other forms of support based on the ES review to further enhance institutional efforts for our students.

5. The new head of OWU's Buildings and Grounds (Peter Schantz) is very engaged in sustainability issues and is fully supportive of a long-term collaboration with faculty, staff, and students focused on the sustainability region. This collaboration will allow some of the programs and projects funded by B&G to engage students as well as fund developments on campus.

6. Collaboration with the city of Delaware means that access to data, equipment, and professional staff over the long-term is ensured. For example, the extensive water testing and monitoring done by the City can be incorporated in our database and used by students to engage in research projects which are pedagogically important and contribute to the needs of the City and the development of the overall sustainability region.

7. Students, faculty, and staff may apply for external funding from funding agencies external to the University. Our organization of the sustainability region and its interrelated research projects provides evidence of a broad vision, documented impacts, and clear pedagogical and research goals that will strengthen our future funding requests.

8. We plan to expand our project to engage K-12 schools in the region which has potential to expand available funding. We envision teachers from local schools working with OWU students, staff, and faculty on specific projects related to the sustainability region. Ohio public school science standards require a local component when studying biology, earth science, etc. and our sustainability region project is poised to serve the needs of K-12 teachers and students.

9. Our project will also be introduced in OWU's summer residential camp for talented and gifted middle school students through hands-on activities led by OWU students participating in the sustainability region project. About 535 6th-8th grade students attend the camp annually.

IX. Intellectual Merit and Broader Impacts

Our proposed project's **intellectual merit** is in the active and engaged manner in which it enhances student understanding of the scientific research process across typical disciplinary boundaries. Students in the natural and social sciences are immersed in tangible, real-world projects working with professionals (on and off campus) that enable contributions to a broader understanding of environment, the regional ecosystem, and sustainability. Additional intellectual merit of the project is generated by the careful integration of human and natural factors in the student research projects, necessary for the study and understanding of sustainability issues. Finally, students will come to appreciate and embrace the complex partnership between the natural and social sciences that must take place to enact meaningful changes in sustainability.

Our proposed project's **broader impacts** grow from the collaborative research between students, university staff and faculty, City professionals and community members. Data from our project as organized and made available in our project database will inform local environmental policy, support local efforts for environmental improvements, and educate citizens about the biodiversity and ecosystem processes. Ours is a model that can be expanded and adopted by other campuses and their communities. The eventual development of a network of similar sustainability region projects would allow for interaction, learning, collaboration, and development of the core ideas in the project over regional to national scales.

Published Literature Cited

Association for the Advancement of Sustainability in Higher Education. 2010. *Sustainability Curriculum in Higher Education: A Call to Action.* AASHE, Denver, CO.

Anderson, L. J., H. Maherali, H. B. Johnson, H. W. Polley, R. B. Jackson. 2001. Gas exchange and photosynthetic acclimation over subambient to elevated CO_2 in a C_3-C_4 grassland. *Global Change Biology* 7(6): 693-707.

Anderson, L. J., J. D. Derner, H. W. Polley, W. S. Gordon, D. M. Eissenstat, R. B. Jackson. 2010. Root responses along a subambient to elevated CO_2 gradient in a C_3–C_4 grassland. *Global Change Biology* 16: 454-468.

Brewer, C. A. & D. Smith. 2009. *Vision and Change in Undergraduate Biology Education*. American Association for the Advancement of Science, Washington, D.C.

Ellis, E. & N. Ramankutty. 2008. Putting people in the map: anthropogenic biomes of the world. *Frontiers in Ecology & the Environment* 6 (8): 439-447.

Gill, R. A., H. W. Polley, H. B. Johnson, L. J. Anderson, H. Maherali, R. B. Jackson. 2002. Nonlinear grassland responses to past and future atmospheric CO_2. *Nature* 417: 279-282.

Hawthorne, T, J. Krygier, M. Kwan. 2008. Mapping Ambivalence: Exploring the Geographies of Community Change and Rails-to-Trails Development using Photo-based Q Method and PPGIS. *Geoforum* 39, pp. 1058-1078.

Jenkins, J. C., D. C. Choinacky, L. S. Heath, R. A. Birdsey. 2003. National-scale biomass estimators for United States tree species. *Forest Science* 49 (1): 12-35.

Krygier, J & D. Wood. 2011. *Making Maps: A Visual Guide to Map Design for GIS, 2nd Edition.* New York: Guilford Publications.

Moore, J. & S. Fitchett. 2004. Connecting Science to the Community at Florida Atlantic University. *In: Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education.* American Association for the Advancement of Science, Washington, D.C.

Olstad, T. 2012. Understanding the Science and Art of Ecoregionalization. *The Professional Geographer* 64 (2): 303-308

Pickett, S. T. A., M. L. Cadenasso , J. M. Grove, P. M. Groffman, L. E. Band, C. G. Boone, W. R. Burich Jr., C. S. B. Grimmond, J. Hom, J. C. Jenkins, N. L. Law, C. H. Nilon, R.V. Pouyat, K. Szlavecz, P. S. Warren, M. A. Wilson. 2008. Beyond urban legends: an emerging framework of urban ecology, as illustrated by the Baltimore Ecosystem Study. *BioScience* 58 (2): 139-150.

Pickett, S. T. A., G. L. Buckley, S. S. Kaushal, Y. Williams. 2011. Social-ecological science in the humane metropolis. *Urban Ecosystems* 14:319-339.

Princeton Review. 2011. 2011 College hopes and worries survey report. http://www.princetonreview.com/college-hopes-worries.aspx

Robbins, P. 2005. *Political Ecology*. Blackwell Publishers.

Rosenzweig, M. 2003. *Win-Win Ecology.* Oxford University Press,

Wharton, E. H., C. L. Alerich, D. A. Drake. 1997. Estimating total forest biomass in New York, 1993. USDA Forest Service. Publications Distribution, 359 Main Road, Delaware, OH 43015.

Student Reports Cited

Callahan, R. & Z. Khalifa. *Building Waste Monitoring and Analysis, Ohio Wesleyan University and Delaware, Ohio Sustainability Region* (student report, Geography 355, Spring 2012)

Carr, A. & S. Kiendl. *Delaware Green Business Survey, Ohio Wesleyan University and Delaware, Ohio Sustainability Region.* (student report, Geography 355, Spring 2012)

Fesz, C. *Wildlife and Water Monitoring in Retention Ponds, Ohio Wesleyan University and Delaware, Ohio Sustainability Region* (student report, Geography 355, Spring 2012)

Graver, T. *Species Diversity and Stored Carbon in Ohio Wesleyan University's Campus Arboretum* (student report, Independent Study, Fall 2009)

Jolliff, S., A. Pinkerton, J. Rux, M. Tice, & K. Varner. *Building Energy Monitoring and Analysis, Ohio Wesleyan University and Delaware, Ohio Sustainability Region* (student report, Geography 355, Spring 2012)

Kusin, J. & J. Reierson. *Anthropogenic Biomes of the Ohio Wesleyan University and Delaware, Ohio Sustainability Region.* (student report, Geography 355, Spring 2012)

Lee, M. *Crowdsourced Environmental Database Proposal* (student report, Geography 360, Spring 2011).

Newman, S. *Solar Energy at OWU: Ohio Wesleyan University and Delaware, Ohio Sustainability Region* (student report, Geography 355, Spring 2012)

Palmer, M. & R. Bowes. *Bishop Green Trail* (student report, Geography 355, Spring 2011)

Rux, J. *OWU Pedagogical Wind Turbine Proposal* (student report, Independent Study, 2011)

Stull, G. *Ecology of a Suburban Jungle: Tree Diversity and Carbon Sequestration on the Ohio Wesleyan University Campus* (student report, Independent Study, Spring and Summer 2009)

Titus, X. *Feral Cat Monitoring and Analysis in the Ohio Wesleyan University and Delaware Ohio Sustainability Region* (student report, Geography 355, Spring 2012)

Vanichstian, L & B. Wood: Lights out Project (student report, Geography 360, Spring 2012)