Summary:

The grand challenge is to prepare for ongoing environmental and demographic changes in order to sustain economic opportunities, protect public health, strengthen Hoosier communities, and maintain valuable ecological services.

Abstract:

Our planet is changing rapidly. Climate disruption, urbanization, and other global transformations are spurring movements of people and animals into new places. Seasonal climatic variation is increasingly out of sync with biological processes, such as leaf emergence and animal migrations. New travel and economic patterns are altering the spread of disease. There is an urgent need for communities in Indiana and around the world to plan for change rather than simply react to problems after they become severe. Successfully adapting to change will require better understanding of human connections to natural systems and the strategic balancing of natural, social, and built capital for thriving, resilient human and natural communities. Our team will refine methods for integrating ecosystems with our social and built infrastructure; improve tracking and management of animals, plants, and microbes critical to agricultural and public health; and innovate new laws and strategies for protecting biodiversity. Effective preparation for change must also invite Hoosiers to reflect on their attitudes and change their behavior. This will require new narratives to help people contextualize and celebrate human-nature relationships, and envision new possibilities for sustaining diverse human communities. Our government, community, and business partners will help us test and demonstrate what we develop.
Preparing for Change
Section 1. The Grand Challenge

We live in an era of rapid environmental and social change. The rise in atmospheric greenhouse gases is warming the Earth, and even aggressive emission reductions will not reverse the climate transformations for generations. Human population continues to increase and the world is steadily urbanizing. Plants, animals, and pathogens are on the move, seeking new niches as land development and range shifts disrupt biomes. These changes impact Hoosiers’ quality of life and the prosperity of Indiana cities. Just as chance favors the prepared mind, planning will increase the odds of effective responses and resilience to these changes. The grand challenge is to understand and predict the changes, and devise strategies that allow people and the environment to flourish. Successful preparation demands transdisciplinary responses, and we will engage the natural and social sciences, humanities, and law and policy in on-the-ground work with public and private partners. Previous efforts to change public attitudes or to shift behavior have fallen short. Our emphasis on new narratives for human interactions with nature will help gain public trust and engage Hoosiers in preparing for a prosperous future.

Section 2. Goals

2.1. Improve predictions of environmental and demographic change.

Preparing for change is necessary whether its cause is anthropogenic or “natural,” and requires better understanding of how Earth systems shape climate, landforms, and biomes. We will identify tipping points in range shifts, evolutionary adaptation, and community composition using animal migrations and plant communities as model systems. Our predictions will frame the challenges and clarify the resilience of our life support systems.

2.2. Extend predictions to ecosystem services and disease vectors.

Environmental and demographic changes expand the ranges and frequency of diseases. We will model the spread of infectious diseases in Indiana, with a focus on mosquito- and tick-borne pathogens, many of which are carried by migratory animals. We will relate our findings to the public health of Hoosiers. We will also apply our tools to better predict and control agricultural pests. We will apply similar models and new technologies to discover where the migratory birds of Indiana travel and develop strategies to maintain their abundance. We will show how migratory birds serve as international ambassadors of conservation, linking Hoosiers to the rest of the world.

2.3. Manage human migration and urbanization.

Human movements are difficult to predict, but have profoundly transformed the Indiana landscape in the past 200 years. Oral and economic history coupled with network science will show how the cultural diversity provided by immigrants and refugees can benefit Indiana.
Section 2 – Goals

2.4. Strengthen urban green infrastructure for prosperity.

Ecological, demographic, and economic pressures are challenging the ability of our cities to provide resources, services and rewarding jobs. Ecosystems provide diverse services, from food and water provisioning to flood and disease control, crop pollination, and recreational benefits. We will promote new methods, such as agriculture in the city, for integrating ecosystem services with urban social and built infrastructure. We aim to transform the practice of urban development so that cities can thrive.

2.5. Shape narratives of change.

To prepare for change, people need stories and images that instruct and motivate. The arts and humanities will play a critical role in shaping public knowledge and attitudes about change and new perceptions of human-nature relationships. We will make accessible accounts of changes in Indiana’s past and engage the public in creating new narratives about their home places and the opportunities to flourish with nature.

2.6. Promote public-private conservation collaboration.

While changes will create new economic opportunities, trade-offs are inevitable. Peaceful resolution of conflicts and incentives to conserve ecosystem services require new collaborations with private property owners and new models for public resource management. We will develop programs to mobilize private land management in the service of public objectives while also generating profits. Case studies will inform the drafting of law and policies to preserve animal migrations, adapt to changes in Earth systems, and bolster social-ecological systems of stewardship.

Section 3. Proposed research and its impact

Preparing for change first requires understanding its scope, then developing strategies to sustain equitable and resilient social-ecological systems. We know that atmospheric carbon dioxide will exceed 600 ppm by 2100, the highest level in the last 25 million years of Earth’s history. By the time current high school students retire, the climate we are familiar with will have shifted hundreds of miles from here.¹

But climate change is only one transformation for which Indiana must prepare. The Indiana landscape has changed dramatically in the past 200 years, especially through the conversion of forests and wetlands to farms, urban centers, and industrialized areas. Cities both drive and are highly vulnerable to planetary change.² Aging, energy- and resource-intensive urban infrastructure is increasingly sensitive to extreme weather events and other global changes.³ Population pressure exacerbates this vulnerability. World population will be 60-70% urban by 2050,⁴ the U.S. population is already 80% urban,⁵ and Indiana will see its greatest population growth in urban and mid-sized counties.⁶
In response to these transformations species are on the move, rearranging themselves into novel ecosystems, and heightening uncertainty about the stability of ecosystem services such as crop pollination. As the world becomes more connected, pests and pathogens move faster than ever. Mosquito species that historically occurred in the tropics have expanded over much of the southern U.S. Ticks are now the most important source of infectious disease in Indiana, and the number of species found in the state has increased from one to three.

To sustain quality of life for growing urban populations while remaining within safe planetary biophysical boundaries, cities must become more resilient, self-sustaining, and carbon-thrifty. Our sense of place and narratives of self must grapple with the changes. Legal frameworks must provide adaptive mechanisms for resolving conflicts over resources. Policies must be informed by science but also built on public trust. We will work on both sides of that equation.

The following six research clusters provide the necessary breadth to navigate the complex social-ecological landscape of this grand challenge (Figure 1). Effective preparation for global environmental change demands interdisciplinary exchange and partnership (Figure 2).

1. **Dynamic Earth Systems: Climates, Landforms, & Biomes** (Team leader: Polly)

Current forecasts predict that Indiana’s climate in 2070 will be similar to central Texas’ today. Rivers and wetlands will change along with precipitation, sediment availability, and vegetation cover, affecting availability of wildlife habitats, agricultural land, and urban sites. We will
investigate **fluvial systems in Indiana** and whether they will **change irreversibly**. We will forecast **flood risks**, erosion rates, and the vulnerability of wetland habitats, agricultural landscapes, and urban centers along Indiana’s rivers.

We will **predict vulnerability of individual species and ecological communities** to extinction and disruptive transformations. Modeling the status and trends of **migratory species** is especially complex because of independent changes at breeding, summering, and migration stopover locations.


Environmental change and human travel have propelled plants, animals, and microbes to disperse and migrate in new ways. Nature reserves are less effective in an era of range shifts and species reshuffling. This research cluster will test new approaches to reduce loss of **biodiversity**, enhance public health, maintain ecosystem services, and contribute to the **sustainability** of Indiana’s agriculture.

A new collaboration between biologists and computer scientists will develop tracking devices for migratory animals whose movements are still unknown. New collaborations between biologists and engineers will advance solutions for **wind energy** that reduce threats to birds and bats.

Globally, **infectious diseases** cause 16% of all human deaths. As the climate warms, mosquito-borne diseases move northward, increasing risk to public health. Last year Indiana suffered more cases of mosquito transmitted chikungunya than the annual average for the entire U.S. from 2003-2013. We will predict how quickly vector-borne diseases will advance. For instance, we will map tick distributions and the incidence of tick-borne disease in the Midwest. We will show how these problems are likely to evolve with climate change. We will also apply our predictive tools to **agricultural pests**, such as soybean rust, which is associated with the invasive plant kudzu.

3. **Human Migration & Urbanization** (Team leader: Sandweiss)

Between 1800 and 1880 two million people moved into Indiana, transforming its landscape and culture. The state will gain another million by 2050, about 15% more than today. This cluster focuses on human culture and attitudes as new ethnic, religious, linguistic, and economic demographics reshape Indiana. We will develop new tools to analyze and predict the types of demographic changes that are occurring in our state and its connections to the world.

**Tolerance** of newcomers, willingness to adjust to change, and visions for the future emerge from the interactions among history, economics, education, and other factors. Historians, demographers, and sociologists will develop new policies to assist in preparing for cultural change in Indiana.

4. **Urban Green Infrastructure** (Team leaders: Reynolds, Filippelli, Gazley)

Green roofs, urban farms, and parks are among the forms of green infrastructure that can contribute to urban economies, reduce dependence on energy- and resource-intensive
technologies, and support **livable, economically vital, and resilient** cities.12-14 Yet complex economic pressures, competing interests, varying levels of ecological literacy, harsh physical conditions, and invasive species challenge efforts to “green the city”.14-16

Applying IU’s special strengths in institutional and governance theory,16-18 we will analyze green infrastructure investments for performance success. Emphasizing community responsibility for **preparedness against natural disasters**,19 we will analyze how urban agriculture and other forms of green infrastructure can **enhance community resilience** to extreme weather events and enable more effective **risk communication**. We will **raise public awareness of human-environment interdependencies**, inspiring new possibilities for sustaining diverse human and non-human communities. Ultimately our work will help to make Indiana a leader in green city design.

**5. Narratives of Change** (Team leader: Irmscher)

Despite decades of warnings, society still struggles to prepare for environmental change. The humanities and the arts play a special role in understanding how scientific ideas are communicated. Our team of humanists, writers, and artists will explore how and why past responses to environmental change have failed to account for the way people understand themselves in relation to their communities and environment. The popular reach of scientific ideas has depended on the metaphors or images in which they were cast,20-24 even at the risk of distortion.25,26 Pervasive images on television and the internet complicate traditional narratives but offer opportunities for **public communication** about environmental change.27 We will rearticulate the challenges for natural and societal resilience, and human well-being.

**Bird migrations** have long been a source of fascination. They force us out of accustomed, anthropocentric, and nationalist paradigms of understanding life. John James Audubon’s *Birds of America* (1827-1838)—a treasure of the Lilly Library and an early record of Ohio River Valley wildlife—attempted to fix quintessentially free moving organisms into place. Modern narratives about migration emphasize habitat connectivity in the face of rapid environmental change.28 We will build on these narratives by creating **oral histories** of the creation of Indiana’s widely acclaimed collaborative conservation project, Goose Pond Fish & Wildlife Area. We will develop a searchable, digital archive of texts on bird migrations, from historical texts to oral histories.

We will also make accessible **visual representations** of human and environmental change in Indiana through the centuries. From the removal of Indians in the 19th century, to the African-American migration into Indiana’s industrial regions in the early 20th century, to the continuing depopulation of rural communities, our state’s history is very much a story of humans on the move. Working with the IU Libraries, we will compile the largest such **online archive** ever assembled. Exhibitions will accompany the release of our searchable database.

**6. Public-Private Conservation Collaborations** (Team leader: Fischman)

Changes in environment, human population, resource use, and economic development require a comprehensive reexamination of conservation law. In the U.S., conservation law focuses on public resources, such as navigable waters and public lands. But most states, including Indiana, contain mainly private property. Without inspiring and motivating landowners, efforts to link
people to ecosystem services, maintenance of biodiversity, and animal migration conservation will fall short.

One important property tool is the **conservation easement**. The U.S. Fish & Wildlife Service manages easements covering approximately 7 million acres,²⁹ and 40 million acres of U.S. land are subject to private conservation easements. We will provide the first comprehensive account of conservation easements of varying types and illustrate new property tools that can be applied precisely and narrowly for particular applications, such as **nitrogen removal from Ohio River and Great Lakes tributaries**. Working with the public agency partners and land trusts, we will pilot new approaches to **habitat network design**, incentives for collaboration, and connectivity along waterways in Indiana.

We will continue Elinor Ostrom’s seminal work to explore how resource users can create their own **institutions of governance** to allocate scarce goods and services. We will apply those principles to Indiana, where we will improve private landowner participation in programs of collaborative management. We will also address international conventions and national policies to make conservation governance more adaptable to change and explore how the law can better promote **adaptive management** to reduce outcome uncertainty over time. We will identify legal changes that yield the most benefit, such as reforming the **Migratory Bird Treaty Act** to effectively address land use decisions that incidentally harm migratory populations.³⁰,³¹

---

**Figure 2.** Our research clusters navigate the complex social-ecological landscape of this Grand Challenge. A few examples of the rich potential for interdisciplinary solutions are illustrated.
Section 4. Resources

4.1 Existing Resources

Our greatest resource is our faculty, who are drawn from almost every relevant unit of the Bloomington campus: COAS (including natural sciences, social sciences, arts and humanities), School of Public Health, SPEA, the Media School, Kelley, Maurer, SGIS, and Informatics & Computing. Faculty for this Grand Challenge are also drawn from IUPUI and Purdue University.

We will leverage many other existing assets and infrastructure. Chief among these are IU’s computing resources. Our GC will exploit multiple existing Big Data geospatial datasets (see Appendix A) whose inclusion in models and visualization will make use of IU’s powerful Karst and Big Red II supercomputing systems.

The Indiana Network Science Institute, Lilly Library, Ostrom Workshop, Center for the Integrative Study of Animal Behavior, and IU Art Museum are among the wealth of world-class institutes, museums, galleries, and centers whose resources will synergistically support the efforts proposed here (Appendix A). The Center for Innovative Teaching and Learning (CITL) and its Service-Learning Program will provide us with the guidance, tools, and connections for launching exciting citizen science and service-learning dimensions of our work. In collaboration with Jennifer Meta Robinson (Anthropology), we anticipate adding a layer of educational research to our project, focused on understanding how culture, technology, and knowledge provide barriers and levers for learning about human-environment relationships and for reconceiving new relationships that are both life affirming and sustainable.

4.2 Future Resources

Implementing our GC will require adding faculty who connect the nodes of excellence among our existing team. To bridge SPEA and COAS, we anticipate two hires in conservation biology, one focusing on behavior, another on range shifts; one hire in urban ecology; and one hire in ecological economics. A hire in spatial disease ecology will bridge SPH, Informatics, and COAS. A hire in environmental humanities will strengthen connections between humanities, the sciences, and policy. A legal scholar with a national reputation for innovation in interdisciplinary conservation solutions will solidify the strong ties between Maurer and SPEA. This GC will also require a full-time administrator, 6 postdocs, 6 graduate research positions (one each per research cluster), a part-time web designer, and 3-4 staff positions for programming, digitizing, and transcribing oral history projects. The importance of data visualization in implementing solutions and changing attitudes will require a new lab for producing innovative graphics and animations. Funds will also go to the Media School, IU Research and Teaching Preserve, and the Lilly Library for support of project activities.
Section 5. Team

Team Leaders (see Appendix B for a full list of team members; Appendix C for biosketches of Team Leaders)

Cluster 1: Dynamic Earth Systems

Cluster 2: Movement Ecology
- Ellen D. Ketterson, Biology IUB (Ph.D., 1974, Indiana University). Evolutionary and behavioral biology. Ketterson is a Senior Research Fellow at the Kinsey Institute and President of the American Society of Naturalists.
- Keith Clay, Biology IUB (Ph.D. Duke, 1982). Ecology and evolution of pests. Clay has served as Director of the IU Research and Teaching Preserve and the Center for Research in Environmental Sciences.

Cluster 3: Human Migration and Urbanization

Cluster 4: Urban Green Infrastructure
- Gabriel Filippelli, Earth Sciences IUPUI (Ph.D., 1994, U. Calif. Santa Cruz). Urban infrastructures and environmental health. Filippelli has served as chair of the Earth Sciences Department and is Director of the Center for Urban Health.
- Beth Gazley, School of Public and Environmental Affairs IUB (Ph.D. University of Georgia, 2004). Gazley specializes in nonprofit management, inter-organizational collaboration, the management of membership associations, and volunteerism.

Cluster 5: Narratives for Change
- Christoph Irmscher, English IUB (Ph.D., 1998, University of Bonn). Literary scholarship, natural history. Irmscher is Director of the IU Wells Scholars Program.

Cluster 6: Public-Private Conservation
- Robert L. Fischman, Maurer School of Law IUB (J.D., 1987, University of Michigan). Law and conservation management. Fischman has managed interdisciplinary workshops on conservation biology and wildlife management; he works closely with the U.S. Fish & Wildlife Service on implementation and education.
Section 6 – Resources

Section 6. Sustainability

Sources of potential support are numerous and our team has a record of success with many.

6.1. Sources of government grants

- The National Science Foundation (NSF) will be quite interested in our work on movement ecology, dynamic earth processes, social-ecological systems, and public-private conservation policy. Relevant programs and their scope include:
  - Division of Environmental Biology: population biology, community ecology, and Long Term Research in Environmental Biology (LTREB)
  - Division of Integrative Organismal Systems: behavioral processes, neural systems
  - Earth-life transitions track in the Sedimentary Geology and Paleobiology program (EAR): impacts of climate on earth systems
  - Social and Economic Sciences (SES) program: resilient infrastructure, decision and risk management, economics, interdisciplinary behavioral and social science research, law & social sciences, and science and society
  - Dynamics of Coupled Natural and Human Systems (CNH): interdisciplinary research on complex interactions between human and natural systems at diverse scales
  - Computer Science: safety of infrastructure services in the face of extreme natural events (tornadoes, earthquakes) which are increasing in frequency

- The National Institutes of Health (NIH) will be interested in our work on health and disease through its National Institute of Allergy and Infectious disease (NIAID) and the NIH Ecology and Evolution of Infectious Diseases (EEID).

- The National Endowment for the Humanities (NEH) and the National Endowment of Arts (NEA) will fund research in history, jurisprudence, and social sciences, with particular attention to projects that are relevant to current conditions of national life, as well as grants for artists, writers, and other creative projects.

- The U.S. Fish & Wildlife Service will fund research that benefits wildlife and habitats, and the U.S. Dept. of Agriculture (USDA) funds projects related to climate change, water quality, and agricultural pests.

6.2. Foundations investing in the environment

We are confident that some of the wealthiest foundations will be interested in our work on urban planning, social injustice, migrations, and infectious diseases. Nationally these include the Bill & Melinda Gates Foundation, the Wellcome Trust, the Ford Foundation, the Templeton Foundation, the Robert Wood Johnson Foundation, the Doris Duke Charitable Trust, the Andrew Mellon Foundation, the National Fish and Wildlife Foundation, and the Russell Sage Foundation; regionally, the Joyce and McKnight Foundations; and in Indiana, the Nina Mason Pulliam Charitable Trust, and the Efroymson Family Fund.

6.3. Private philanthropy

We have a compelling story to share with alumni and other potential donors who have a commitment to the maintenance of biodiversity, the economic well-being of the state, healthy outdoor experiences, more livable cities and a better environment for their children. There are, for example, 20 million bird watchers in the U.S., many of them people of great means. With the advice of the IU Foundation and the Media School we will craft an appeal that effectively communicates our passion for our work, creates a sense of urgency, and lays out a timeline of achievable goals with specific milestones.
Section 7. Partners

These existing external partners have already agreed to be a part of this Grand Challenge. They bring practical expertise, resources, and connections to help implement the proposed research to ensure tangible benefits for Indiana communities. We have long-standing relationships with most of these partners through research, service-learning, outreach and/or policy collaborations. Research and outreach to restore urban woodlands with City of Bloomington Parks and Recreation, integration of art and science to protect migratory birds with WonderLab, and policy development for land trusts with the Conservation Law Center are examples among many on-going projects. Our partners share our goal to prepare Indiana to flourish in a changing world, and our existing projects provide a foundation upon which to build.

7.1 City of Bloomington
   Economic and Sustainable Development (Danise Alano, Jacqui Bauer)
   Parks and Recreation (Mick Renneisen, Steve Cotter)
   Planning and Transportation (Tom Micuda, Linda Thompson)

7.2 City of Indianapolis
   Parks and Recreation (Elaine Dillahunt)
   Office of Sustainability (Melody Park)
   Keep Indianapolis Beautiful (David Forsell)
   Indianapolis Cultural Trail, Inc. (Kären Haley)

7.3 Indiana NGOs
   Bloomington Urban Woodlands Project (Heather Reynolds)
   Conservation Law Center (William Weeks)
   Cope Environmental Center (Alison Zajdel)
   Indiana Urban Forest Council (Holly Jones)
   Indianapolis Zoo (Robert Shumaker)
   The Nature Conservancy of Indiana (Mary McConnell, Ellen Jacquart)
   Monroe County Identify & Reduce Invasive Species (Ellen Jacquart)
   Sassafras Audobon Society (Geoff Conrad)
   Sycamore Land Trust (Christian Freitag)

7.4 Indiana Business & Industry
   Citizens Energy Group (John Trypus)
   Eco Logic, LLC (Spencer Goehl)

7.5 US Government
   US Fish & Wildlife Serv. (Glen Salmon, Midwest Landscape Conservation Cooperative)
   US Forest Service (Lynne M. Westphal)

7.6 National and International NGOs
   Smithsonian National Zoo, Migratory Bird Center (Peter Marra)

7.7 Other University Partners
   Program on Economics, Law, and Environment, U Arizona (Dean Lueck)
Section 8 Metrics

Our research will produce diverse benefits for Indiana and ideas that can be emulated by communities around the world. Our approach to assessing outcomes is to establish a suite of activities for each main goal and separately assess the completion of the activity and its impact. The following examples illustrate activities that have short-, medium-, and long-term impacts (Table 8.1).

**Table 8.1. Examples of preparing for change goals, practical mechanisms, metrics and impacts.**

<table>
<thead>
<tr>
<th>Goals</th>
<th>Mechanisms</th>
<th>Metrics</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve predictions of environmental and demographic change</td>
<td>Create fluvial forecast models for Ohio, Wabash &amp; White River systems with</td>
<td>Completed modeling runs and reports aimed at city and land managers</td>
<td>Long term: informed planning for agricultural, transport, and urban development along Indiana's rivers</td>
</tr>
<tr>
<td></td>
<td>reports aimed at city and land managers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predict changes in ecosystem services and disease vectors</td>
<td>Develop tracking devices for following animal movements, construct pest &amp;</td>
<td>Completed range maps incorporating knowledge gained from tracking devices; best practices adopted</td>
<td>Medium term: reduced incidences of mosquito &amp; tick born diseases; biodiversity maintained</td>
</tr>
<tr>
<td></td>
<td>disease range maps and develop associated management best practices for governments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage human migration and urbanization</td>
<td>Assess attitudes toward Indiana's urban infrastructure and natural resources with oral histories of recent Asian immigrants</td>
<td>Completed interviews, published histories</td>
<td>Short term: sharing of attitudes and aspirations across Indiana's increasingly diverse population</td>
</tr>
<tr>
<td>Strengthen urban green infrastructure for prosperity &amp; resiliency</td>
<td>Partner with business &amp; government to conduct cost-benefit analyses of green vs. conventional infrastructure</td>
<td>Completed analyses, number of communities implementing new green infrastructure projects</td>
<td>Medium &amp; long term: more livable, economically vital &amp; resilient cities</td>
</tr>
<tr>
<td>Shape narratives of change</td>
<td>Create a Lilly Library exhibit and online exhibit, with link to full texts and images, of Indiana's natural history from the colonial period to present</td>
<td>Number of visitors to physical and online exhibits; number of presentations made to state natural history societies</td>
<td>Short-term: increased awareness of environmental change among Hoosiers</td>
</tr>
<tr>
<td>Develop public-private conservation tools</td>
<td>Inventory conservation easements &amp; demonstrate property tools</td>
<td>Completed inventory, number of landowners applying property tools</td>
<td>Medium term: increased acreage of protected lands, higher water quality</td>
</tr>
</tbody>
</table>
References Cited

5. U.S. Census Bureau, ask.census.gov, 2015.
6. Thriving Communities, Thriving State, Indiana University Public Policy Institute, 2015.
References Cited

Appendix A. Existing Resources

A.1 Arts & Humanities
- Consortium for the Study of Religion, Ethics & Society
- Grunwald Gallery
- Indiana Fine Arts Museum
- Indiana Magazine of History (http://www.indiana.edu/~imaghist/)
- Lilly Library
- Poynter Center for the Study of Ethics & American Institutions

A.2 Business
- Indiana Business Research Center (http://www.ibrc.indiana.edu/data.html). Collects and provides statistics on the state of Indiana, including demographic, agriculture, education, labor, urbanization, and economic data.

A.3 Computing
- The cyber infrastructure at Indiana University is among the best at any university in the world. Its supercomputers, data storage systems, visualization environments, and access to high performance research networks allow researchers to achieve breakthroughs in scholarship by making possible new calculations, analyses, and visualizations of massive amounts of data.
- Karst and Big Red II computing clusters (https://kb.iu.edu/d/alde). High throughput computing on these systems will be used for modeling. Affiliated research database complex (RDC) and research file system (RFS) will be used for storage and analysis of large data sets.
- Visualization Tools (http://www.avl.iu.edu/). Virtual-reality theater, ultra-high resolution display wall, and IQ walls for visualization large, complex, or other datasets, including migration networks.

A.4 Earth Systems
- Climate, landform, and species occurrence data resampled at 50 km grids (http://mypage.iu.edu/~pdpolly/Data.html). Global and regional data on climate, topography, vegetation cover, geographic ranges of vertebrate species resampled for easy integration with fossil and geological data for studying dynamics of species in past, present and future. Assembled with NSF support.
- Fluvial monitoring and modeling lab (http://geology.indiana.edu/edmonds/sedSystems/). Lab operated by Edmonds maintains fluvial modeling software (Delft3D), drone-based topographic mapping, acoustic Doppler current profiler, and sediment samplers. Sediment dating provided by the Craft Lab using lead and cesium.
- Indiana Map (http://indianamap.org). GIS data portal for the state of Indiana operated by the Indiana Geological Survey. Provides high-resolution topographic, ground cover, land use, infrastructure, water and wetland bodies, physiography, and modern and historical census data.
- Paleobiology Database (https://paleobiodb.org/). NSF-funded database of fossil occurrences built by the research community.
- Neotoma Database (http://www.neotomadb.org). NSF-funded database of fossil occurrences focusing on the Quaternary period (the most recent unit of geological time, 2.5 million years to the present) containing data on occurrences of vertebrate animals,
plants, and plant pollen that will be used to reconstruct past geographic ranges and rates of change.

- Stable Isotopes Lab, Indiana University Mass Spectrometry Facility.

**A.5 Environmental Sciences**
- Integrated Program in the Environment

**A.6 Life Sciences**
- Center for the Integrative Study of Animal Behavior [CISAB]
  - CISAB Core Laboratory
- IU Research and Teaching Preserve [IURTP]
- Psychological and Brain Sciences
- Imaging Research Facility [IRF]
- Center for Genomics and Bioinformatics [CGB]

**A.7 Parks and Recreation**
- Eppley Institute for Parks & Public Lands

**A.8 Public Health**
- Center for Public Health, IUPUI
- Office of Community Health Partnerships

**A.9 Policy and Law**
- Conservation Law Center

**A.10 Social Sciences**
- Center on Congress at Indiana University
- Indiana University Network Science Institute
- Mathers Museum
- Ostrom Workshop

**A.11 Teaching and Learning**
- Center for Innovative Teaching and Learning
  - Service-Learning Program
Appendix B. Team Members

Research cluster affiliations: 1. Dynamic Earth systems; 2. Movement ecology; 3. Human migration; 4. Urban green infrastructure; 5. Narratives of change; 6. Public-private conservation; TL. Team leader. (Roles, additional affiliations, or training of particular relevance to the GC are indicated in parentheses.)

B.1 Indiana University Bloomington

Center on Congress

Lee Hamilton (Director) 4

College of Arts and Sciences

Anthropology

Eduardo Brondizio 3, 5
Jennifer Meta Robinson (Professor of Practice in Pedagogy) 1-6

Apparel Merchandising and Interior Design

Marleen Newman (Architect) 4

Biology

Jonathan Atwell 2
Keith Clay TL
Greg Demas 2
Adam Fudickar 2
Roger Hangarter 2
James Hengeveld 2
Susan Hengeveld 2
David Kehoe 4
Ellen Ketterson TL
Jay Lennon 2
Rich Phillips (Director, IU Research & Teaching Preserve) 4
Heather Reynolds TL

Economics

Lee Alston (Ostrom Workshop) 6

English

Vivian Halloran (American Studies) 4
Scott Russell Sanders 2, 5

Geography

Ishan Ashutash 4
Elizabeth Dunn (School of Global and International Studies) 3
Dan Knudsen 4

Geological Sciences

Douglas Edmonds 1
Edward W. Herrmann (Anthropology) 1
Claudia Johnson 1
Chanh Q. Kieu 1
P. David Polly TL
Paul Staten 1

History

Alex Lichtenstein 3
Appendix B – Team Members

History and Philosophy of Science and Medicine
James Capshew 4

Political Science
Michael D. McGinnis 6

Sociology
Ann McCranie 3
Bernice Pescosolido 2,3

Religious Studies
Lisa Sideris 4

School of Informatics
Geoffrey Brown 2
Mehmet Dalkilic 1,2

Kelley School of Business
Matthew Grimes 4

Maurer School of Law
Daniel H. Cole (Political Science & Ostrom Workshop) 2, 6
Robert L. Fischman 4, 6
W. William Weeks (Conservation Law Clinic) 2, 6

School of Fine Arts
Betsy Stirratt (Director, Grunwald Gallery) 2, 5

School of Public and Environmental Affairs
Shahzeen Attari 6
Burnell C. Fischer 4, 6
Brad Fulton 4
Beth Gazley 4, 6
Vicky J. Meretsy (Biology) 2, 6
Sarah Mincey (IPE, Ostrom Workshop) 4
Flynn Picardal 4

School of Public Health

Epidemiology and Biostatistics
Robert C. Reiner, Jr. 4, 6

Environmental Health
Alan Ewert (Recreation, Park, and Tourism Studies) 4

Recreation, Park, and Tourism Studies
James R. Farmer 4, 6
Lynn Jamieson 4
Appendix B – Team Members

Doug Knapp 4
Rasul Mowatt 4
Bill Ramos 4
Steve Wolter (Eppley Institute for Parks and Public Lands) 4

The Media School

James Shanahan (Dean) 5

B.2 Indiana University-Purdue University Indianapolis

Fairbanks School of Public Health

Max Moreno 2, 4

Robert McKinney School of Law

Eric Dannenmaier 4

School of Liberal Arts

Communication Studies

John Parrish-Sprowl (Director, Global Health Communication Center) 4

Earth Sciences

Gabriel Filippelli (Director, Center for Urban Health) TL
Pierre-Andre Jacinthe 4

Geography

Jeffrey Wilson 4

History

David Bodenhamer (Executive Director, The Polis Center) 4
Jason Kelly (Director, Arts and Humanities Institute) 4

B.3 Purdue University

College of Science

Biological Sciences

Jeffrey Dukes (Climate Change Research Center) 1, 2
Esteban Fernandez-Juricic (Biological Sciences) 2