2012 Interdisciplinary Graduate Education Program In

INTERFACES OF GLOBAL CHANGE (IGC)

IGC Participating Departments/Colleges:

Fish and Wildlife Conservation, College of Natural Resources & Environment
Biological Sciences, College of Science
Civil and Environmental Engineering, College of Engineering
Urban Affairs and Planning, College of Architecture and Urban Studies
Plant Pathology, Physiology, and Weed Science, College of Agriculture & Life Sciences
Biological Systems Engineering, Colleges of Agriculture & Life Sciences and Engineering
History/ Science & Technology in Society, College of Liberal Arts and Human Sciences
Forest Resources & Environmental Conservation, College of Natural Resources & Environment
Geosciences, College of Science
Entomology, College of Agriculture & Life Sciences

Alphabetized List of Participating Core Faculty[1]

Paul Angermeier	FIW/CNRE	Habitat, Conservation Biology
Jacob Barney	PPPWS/CALS	Invasive Species (plants)
Jeb Barrett	BIO/COS	Climate Change
Mark Barrow	HIST & STS/CLAHS	History of Environ. Science/Policy
Lisa Belden	BIO/COS	Disease, Community Ecology
Deborah Brosnan[2]	Brosnan Center/BIO	Policy, Science, and Society
Dana Hawley	BIO/COS	Disease Ecology
William Hopkins **(P.I.)**	FIW/CNRE	Pollution, Physiological Ecology
Leigh Anne Krometis	BSE/CALS & COE	Pollution, Land Use
Ignacio Moore	BIO/COS	Stress & the Environment
Amy Pruden	CEE/COE	Pathogen pollution, microbiology
John Randolph	UAP/CAUS	Land Use, Policy, Urbanism
Scott Salom	ENT/CALS	Invasive Species (invertebrates)
Steven Schoenholtz	FREC/CNRE	Water Resource Conservation
Madeleine Schrieber	GEO/COS	Water Quality, hydrogeology
Jeff Walters **(co-P.I.)**	BIO/COS	Habitat, Policy, Conservation

[1]We have limited our core faculty to maintain a strong group dynamic and establish meaningful interactions. However, because the IGC IGEP will complement the new Center for Global Change on campus, there will be many opportunities for > 20 other faculty within the Center to recruit additional students into the program. In addition, our IGEP students will take graduate coursework and interact closely with faculty in several other academic units involved with the Center including Statistics (COS) and Bioinformatics (VBI).

[2]Dr. Brosnan is the founder & director of the Brosnan Center http://www.brosnancenter.com. She joined the VA Tech community in 2012 as an adjunct faculty member in BIO (COS). She will be working with IGC trainees in the classroom, serving on their graduate committees, and leading workshops on the role science should play in guiding environmental policy and how scientists can better communicate with decision-makers.

Introduction

Rationale and Need: Human domination of the Earth has created a myriad of problems that threaten biodiversity and essential ecological processes, and in doing so jeopardize the long-term welfare of society. Current rates of extinction of species are up to 1,000 times higher now than before human dominance. Such loss of species diversity destabilizes ecological processes resulting in cascading effects through ecosystems. It is widely acknowledged that the five greatest anthropogenic threats to global health and biodiversity are habitat loss, introduction of non-native species, pollution, disease, and climate change. Although there is considerable research on each of these individual global threats, much less is known regarding how these factors interact with one another (Figure 1). For example, how can climate change affect the distribution of invasive species that are important vectors of disease? These types of interactions are critical because all habitats experience the simultaneous pressure of two or more of these threats. Thus, looking to the future, a more interdisciplinary understanding of these anthropogenic factors is necessary to inform public policy (Figure 2), minimize further environmental degradation and loss of biodiversity, and to promote sustainable solutions to the greatest environmental challenges of the 21st century.

The interaction of these five global threats represents the next frontier in global change science. This emerging frontier has been recognized in the recent literature (e.g., numerous scientific review papers; NRC Report on Grand Challenges in Environmental Sciences), has been a focus of major international assessments (e.g., Millennium Ecosystem Assessment; 2012 Pellston Workshop), and has been highlighted in recent major initiatives by funding agencies (e.g., NSF,NIH, DOD). However, we are aware of no graduate training program in the nation that specifically focuses on the interfaces of these global threats. Clearly, such interdisciplinary training will be necessary for the next generation of scientists to transcend disciplinary boundaries and address this new frontier of global environmental challenges.

Virginia Tech is not currently recognized as the world leader on any single global threat, but we have leading experts and disciplinary strengths across Colleges on all of these global changes. Thus, we are in a strong position to claim a unique niche for ourselves in global change science. In recognition of this unique position, VA Tech is establishing The Center for Global Change (Appendix, signatures), an interdisciplinary cross-campus consortium of faculty dedicated to training the next generation of scientists studying the complex interactions among global threats to environmental integrity. An IGEP will serve as an important supporting mechanism to train doctoral students within the new Center, and the larger Center initiative will help attract and support our new IGEP trainees.

Program Goals: We intend to establish an interdisciplinary graduate training program unlike any other in the world. "Global Change" has unfortunately become synonymous with "Climate Change" and graduate training programs across the U.S. reflect this misnomer. Thus, a more holistic training model is necessary to address the multidimensional aspects of global change. The goals of the IGC IGEP are to provide each trainee with a broad perspective on **A)** how the five major global changes *interact* to impact biodiversity and environmental health (Figure 1), **B)** the societal causes and consequences of these ecological problems, and **C)** the role that science can play in resolving these issues by informing sound environmental policy (Figure 2).

Description

Long Term Education Goals: The overarching goal of the IGC IGEP Program is to provide doctoral students with a unique interdisciplinary perspective and skill set that will enable them to tackle complex problems at the interfaces of global change. Specifically, the program will:

- Create a learning community of scholars with a deep and holistic understanding of how the major global threats can interact to influence the environment and society.
- Foster an environment where students learn the "languages" of scholars in different fields, breaking down traditional disciplinary borders to facilitate interdisciplinary collaboration.
- Inspire young scientists to consider how their research, both the questions they pursue and the scientific approaches they utilize, may influence public policy and society.
- Create an environment where young ecologists, social scientists, and engineers interact closely and learn how to effectively communicate their scientific findings with one another and to decision-makers.

There is no other graduate program in the nation that pursues these cumulative goals.

Figure 1. Complex Interactions among the five major global threats that comprise the IGC *Interface I*.

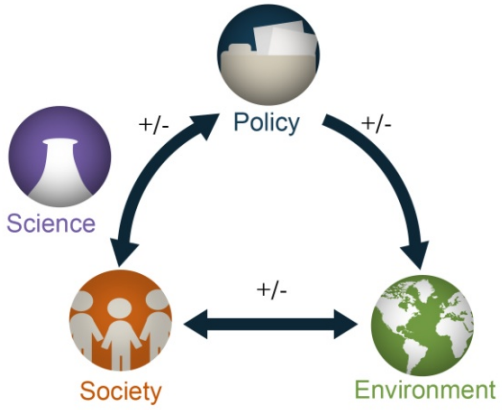

Figure 2. Interactions among society, science, and environmental health that comprise the IGC *Interface II*.

Intellectual Focus: The IGC IGEP will provide the next generation of scientists with a unique perspective and skill set to address the most challenging environmental issues facing society today, centered around two critical interfaces: *Interface 1*: Interactions among the 5 global threats (Figure 1); and *Interface 2*: Science and Society (Figure 2). While there are dozens of global *climate* change graduate programs in the U.S., there is only one other program (University of Arizona, minor in Global Change) that offers graduate training in the broader phenomenon of Global Change. Thus, to our knowledge the IGC IGEP will be the first graduate program in the nation to specifically focus on the *interfaces* of the major global threats to environmental health and society. Being at the next frontier of inquiry in applied ecology will delineate VA Tech as a leader in Global Change science, uniquely position us for emerging funding opportunities (e.g., NIH Environmental Influences on the Microbiome), and enable us to recruit and train the brightest and most passionate students and faculty to tackle the world's most complex environmental problems.

Coursework & Other Training Requirements: IGC trainees will engage in a combination of new and existing coursework (*Interfaces I & II*, see Appendix) that is unique at Virginia Tech. Current curricula in science and engineering at Virginia Tech do an excellent job of providing scientific training within narrowly focused areas, but none of these programs emphasize the interfaces of global threats because the necessary expertise is so dispersed across campus. Likewise, there are excellent programs on campus that emphasize various aspects of science and society (e.g., UAP and STS), but graduate students in COE, CNRE, CALS, and COS are not adequately engaged with these programs. Thus, our goal is for each IGC student to gain depth in their specific scientific area of expertise, while simultaneously gaining breadth in the multifaceted realm of global change and the science-policy interface. The program will provide enough flexibility to meet the needs of each individual student, but sufficient structure to ensure that students gain the broad perspective expected in our training program (courses, Appendix). In addition to coursework, IGC trainees will also be required to:

- Submit a nationally competitive interdisciplinary proposal (e.g., NSF GRFP, EPA STAR Fellowship, NIH Individual NRSA, NSF DDIG) that emphasizes both interfaces of the IGEP.
- Attend a workshop at VT each year on analytical skills for integrating and interpreting large amounts of data from diverse fields (e.g., bioinformatics, statistical, & systems approaches).
- Attend a workshop each year at VT addressing policy and communication issues (e.g., training by the Brosnan Center on communication between scientists & decision makers).
- Host a seminar speaker relevant to the IGC or organize speakers for one of the above workshops.

Recruitment and Retention: IGC IGEP trainees will be recruited from around the world. The core faculty members already recruit some of the brightest graduate students in their respective disciplines, and these strong disciplinary reputations will be key towards recruiting trainees seeking to address more interdisciplinary aspects of global change. Graduate students will be recruited using forthcoming websites for the Center for Global Change and the IGC IGEP, international advertisements through professional societies, IGC IGEP fliers/brochure disseminated for posting in other institutions, and by interacting with students at national meetings and invited seminars. We will target underrepresented groups by advertising on appropriate websites and by using resources supplied through the Office of Graduate Recruitment & Diversity Initiatives (e.g., Coordinated School Visit Program). Because of our unique focus on the interactions of global threats to environmental health and the science-policy interface, we will be highly competitive with established programs in global change which focus more narrowly on global *climate* change. Some students recruited to the program will be funded for the first year through the IGEP funds and others will be supported entirely off of extramural funds. Thereafter, all students will be supported predominately from a variety of external sources (Appendix).

We expect high retention of our IGC IGEP trainees for the following reasons. 1) No student will be accepted to the program unless adequate funds are available to support their training. The core faculty has an extraordinary track record of securing extramural funding (Appendix). 2) We will create a strong sense of community amongst the IGC IGEP fellows and faculty (see below). 3) The P.I. and co-P.I., who currently serve as curriculum chair (FiW) and graduate program director (BIO) in their respective departments, will maintain an open door

policy for IGEP participants so that logistical, curricular, and interpersonal issues can be addressed in a timely manner. 4) Graduate students will undergo annual assessments to quantify their progression in the program and will receive meaningful written reviews and suggestions for improving their graduate experience.

Building a Global Change Community: We will develop a community of scholars seeking to resolve the most pressing issues related to global change. Specific examples of how we will promote a sense of community include:

- Annual 1 cr Graduate Seminar Courses will bring students and faculty together weekly to discuss primary literature on how the major global threats interact and the science-policy interface. Frequent discussions will ensure continuity among student cohorts, create mentorship relationships between more established students and new trainees, generate new research ideas, and help identify areas for collaboration.
- Invited seminar speakers and workshops. IGC graduate students will invite at least two seminar speakers each semester that are interdisciplinary leaders in global change research and/or policy. In addition, we will organize two workshops each year for faculty and trainees, dealing with 1) analytical approaches to integrating diverse data (e.g., systems theory) and 2) the science-policy interface and communication.
- Social Events and Newsletter. A variety of events will be organized each year, including potluck dinners for the invited seminar speakers and workshop leaders, holiday events, and an annual banquet to showcase graduate interdisciplinary research and the accomplishments of trainees in the program. We will also distribute a quarterly newsletter that contains updates and announcements, highlights the accomplishments of members of the team, and profiles one of our graduate trainees in each issue (e.g., a bio and description of research and accomplishments)

Program Sustainability: Because of the broad appeal of our IGEP across colleges on campus and the simultaneous development of the new Center, we will draw trainees from diverse disciplines into the program. Our broad appeal will allow us to reach an anticipated steady state of ~15 doctoral trainees by year 5 of the program. Funds for these trainees will be derived from external grants and supplemented with departmental assistantships. Our funding base and track record of collaboration are both outstanding and will enable us to support trainees admitted to the program. See Appendix for details.

Program Assessment/Outcomes: In coordination with Dr. Steve Culver in the VT Office of Assessment and Evaluation (Signature, Appendix), we will use quantitative and qualitative methods to continuously improve our IGEP. Data-driven decisions for continuous improvement will be based on an array of metrics including: the number of trainees in the program, retention and graduation rates of trainees, job placement of trainees, quantity and quality of publications, number of publications with two or more trainees/faculty as co-authors, number and funding amount of interdisciplinary extramural grants and graduate fellowships funded, and external recognitions of our students (e.g., awards from professional societies). We will have a formal annual assessment of the program by faculty and trainees to include questions related to satisfaction with the curriculum, leadership, interdisciplinary training, and scholarly community.

Appendix: Desired Criteria

1. Current Funding
2. Plan for Securing Funding
3. Fostering Interdisciplinarity
4. Integrating Disciplines in the Curriculum

1. Current Funding Base. The core faculty members in the IGC IGEP already have a remarkable track record of funding and collaboration. The IGC core faculty have a broad and highly successful funding portfolio, that currently includes 83 grants exceeding $21.9 Million from sources that include NSF, NIH, DOD, DOI, USDA, DOE, TVA, NGOs, state agencies, and industry. Currently, $5.6 Million of this funding represents collaborative projects among members of our core faculty. By bringing even more faculty together with complementary expertise from around campus, we will build from this remarkable funding base with even more innovative collaborations, grants, and training opportunities for graduate students.

2. Plan for Securing Extramural Funding. We have three strategies for securing new funding to expand our current large funding base: 1) Training Grants, 2) Graduate Student Fellowships, and 3) Extramural Collaborative Grants.

1) We intend to apply for a minimum of one training grant (i.e., NSF IGERT) in the second year of the IGEP. This training grant will build upon our existing expertise on each of the individual global threats, but will emphasize A) how the *interactions* amongst these threats can influence ecosystem processes, wildlife and human health, and biodiversity; and B) how science can influence environmental policy to mitigate these undesirable effects.

2) Graduate trainees are required to submit at least one national fellowship proposal (e.g., NSF, NIH, DOE, EPA). Most of our core faculty already mentor students who have received these awards. We intend to continue this track record and create an environment where this requirement is an important learning experience for the students. Using the fall seminar course (1 cr) as a platform, trainees will be required to provide peer review of other students' proposals and present their ideas and study designs to the group. Iterative feedback will not only help the students generate successful proposals, but will also prepare them for grant writing later in their careers. The PI (Hopkins), who has served on the NSF GRFP panel the last four years and has considerable experience mentoring NSF and EPA fellows, will lead a roundtable discussion each fall about the attributes of successful fellowship proposals.

3) The core faculty of the IGC IGEP Program will also pursue diverse funding opportunities to support doctoral students in the program. Our interdisciplinary proposals will be highly competitive with NSF, NIH, DOD, USDA, EPA, USFWS, DOE and specific programs within these agencies (e.g., NSF CREATIV, Dynamics of Coupled Natural and Human Systems, and Macrosystems Biology; NIH Environmental Influences on the Microbiome; DOD SERDP program) because of their focus on interfaces of global threats and interdisciplinary approaches to solving them. Provided below are three examples of training opportunities we intend to create with the support provided by the IGEP and complementary extramural funding.

Pollution, the microbiome, invasive pathogens, and disease (NSF, NIH). The microbiome, the collection of microbes living on and inside organisms, plays a key role in the health of their host organisms. Emerging evidence suggests that environmental pollutants can change the diversity and composition of an organism's normal microflora, and this may subsequently influence its susceptibility to disease. We (Belden, Hopkins, Bioinformatics, & Statistics) will train students to examine the effects of pollutants on the skin microbiota of amphibians, and how changes to the epithelial microbiome influence their susceptibility to the most catastrophic pathogen to ever affect wildlife, chytrid fungus. In many parts of the world, chytrid fungus is believed to be an invasive pathogen but the underlying mechanisms of its emergence remain a mystery. Compromised normal defenses, such as anthropogenic effects on epithelial microfloral communities, could be a key to understanding a disease that eliminates entire species of amphibians in the wild each year. We will focus our efforts specifically on how amphibian microflora are influenced by coal combustion wastes, the second largest solid waste stream produced in the world. Management of these wastes has been one of the most contentious policy debates in the U.S. regarding waste management for the last two decades, and our trainees will become well acquainted with the viewpoints and languages of the diversity of stakeholders involved with this important and unresolved debate.

Genomics, subspecies designations, and environmental policy (DOI). The Endangered Species Act is arguably the nation's most powerful piece of environmental legislation. Whether or not organisms receive protection under the Act often depends on whether or not they are deemed to constitute a subspecies. Although many tools have historically been used to differentiate subspecies, modern genomic techniques have revolutionized our ability to identify subspecies. Those responsible for enforcing the Act, in both the legal and policy arenas, are often confronted with scientific studies with conflicting conclusions about subspecies status, and in many cases these conflicts can be further complicated by stakeholders with vested interests in the outcome of the decision. We (Brosnan, Walters, Barrow, & Bioinformatics) will train students to understand the historical and modern methods for designating subspecies. A formal scientific assessment of these methods, including a variety of real-world case studies, will be provided to policy-makers so that they have the necessary expertise to evaluate the science used in their decisions.

Climate change, land use (habitat), invasive species, water quality, and disease (EPA, USDA, NIH, NSF). Changing climatic conditions and a growing human population will alter patterns of agricultural (crops and livestock) land use and urban development. For example, increasing demand for food in areas that are becoming increasingly inhospitable for agriculture due to drought and nutrient impoverished soils has resulted in more intensive agriculture in other areas. Simultaneous emergence of resistant agricultural pathogens and invasive pests has increased usage of pesticides and antibiotics in some of these areas. The consequences of such shifts in land use can be profound for local ecosystems and ultimately society, including reduced immunocompetence in biota and outbreaks of wildlife disease that destroy natural resources (e.g., fish kills). Our interdisciplinary team (<u>all</u> members) is uniquely qualified to train students to examine how changes in land use and chemical control measures for invasive species can influence water quality, immunocompetence, and emergence of disease in fish and

wildlife. Highly interdisciplinary perspectives on these complex issues are required to inform policy makers about land development, pesticide and antibiotic use, and watershed management.

3. Fostering Interdisciplinarity. Our 16 core faculty members represent a diversity of scientific and societal perspectives as well as a community of scholars spanning all stages of their academic career. We represent 10 departments and 6 colleges on campus, and one off-campus center, with strong inclusion of both the sciences and social sciences (UAP, HIST, STS, and Brosnan Center). Reaching across so many academic units is required to achieve our vision for interdisciplinary training at both of our *Interfaces* (*I* and *II*). Faculty from these diverse departments will offer formal coursework in their areas of expertise, participate in the GRAD 5134 and Graduate seminar courses, and participate in the multitude of IGC IGEP social events. Importantly, we have deliberately drawn young faculty from various Colleges on campus to be part of our core team. Inclusion of younger Assistant and Associate professors in the IGC IGEP will foster interdisciplinarity early in their careers at VT, expose them to broad opportunities and collaborations around the VT campus, and is critical to the long-term sustainability of our interdisciplinary program (and other programs on campus).

4. Interdisciplinary Curriculum. Our interdisciplinary curriculum requires that each student take at least 12 hrs of core coursework designed to address the two Interfaces of Global Change (*Interface I and II*; see below). The remaining coursework will be comprised of electives pertinent to the student's area of research emphasis (e.g., ecology or engineering) and requisite skillsets (e.g., GIS or statistics). Importantly, these elective courses are not currently offered in any single College at Virginia Tech, requiring our trainees to extend themselves across the disciplinary landscape of the campus. For example, a trainee studying how *climate change* influences the *invasiveness* of a non-native plant and the repercussions of using *pesticides* to control this invasive species could take 1) PPWS 5604 Biological Invasions: Ecology of Invasive Species, 2) CEE 5124 Fundamentals of Environmental Toxicology, and/or 3) BIOL 5114 Advanced Global Change Ecology.

Interface I (Interactions of Global Change Threats): Students will take 7 cr of new courses that will be developed as part of the IGC IGEP. Course Descriptions accompany these new courses.

- *Interfaces of Global Change (Crosslisted Seminar each fall, 1cr each, 4 cr total).* Brown bag discussion of primary literature on how the five major threats to global biodiversity interact to affect the environment and how science can inform public policy to influence these interactions. Students will be required to read and discuss primary literature with their peers and the IGC Faculty each week.
- *Interdisciplinary Challenges in Global Change Research (GRAD 5134, 3 cr)*: This reading-, writing-, and discussion-intensive capstone course will be developed and team-taught by several IGC core faculty. Trainees will take this course after completing their other major coursework. Trainees will continue to hone their scientific and technical breadth of knowledge related to global change, but this course will also emphasize a) the practical challenges associated with conducting interdisciplinary research and b) the role of science

in society and policy. Using a variety of case studies and active learning techniques, we will cover topics to include: institutional, interpersonal, and disciplinary challenges in interdisciplinary research; working in teams; leadership; discussing science with the public, press, and policy makers; science vs. advocacy; and ethics.

Interface II (Interaction of Science and Society): Students will take at least 5 cr of courses that are currently offered at VA Tech representing two areas:

- *Environmental policy, law, or history course (2-3 cr)*. Hist 5694 American Environmental History ; ASPT 6004 Bioethics, Biopolitics, Biohistory; CEE 5984 Ethics in Engineering, Science, and Public Policy; UAP 5134 Land Use and Environment: Planning and Policy; STS 5614 Science and Technology Policy; or NR 5984 Watershed Assessment, Management, and Policy (*2cr*)
- *Conservation Biology or Sustainability course (2-3cr)*. BIOL 6004 Advanced Conservation Biology; NR 5984 Biodiversity Conservation and Environmental Sustainability (*2cr*); or UAP 5134 Land Use and Environment: Planning and Policy.

Coursework Timeline

	Fall	Spring
Year 1	Global Change Seminar; Electives	Policy, Law, or History; Electives
Year 2	Global Change Seminar; Conservation/Sustainability	GRAD 5134; Electives
Year 3	Global Change Seminar[1]	----------
Year 4	Global Change Seminar[1]	----------

[1]Students will complete their primary coursework during the first two years of study, and will then advance to candidacy in their respective department. Thereafter, students will continue to enroll in the Global Change Seminar course to stay up on the literature, maintain their connection to the IGC community, and develop relationships with new cohorts of students.

Virginia Tech

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

11-5-12

Dear Dean DePauw,

We enthusiastically support the IGEP on "Interfaces of Global Change" proposed by an interdisciplinary team of researchers from the University community and led by Assoc. Prof. William Hopkins (FiW, CNRE) and Prof. Jeff Walters (BIO, COS). This highly interdisciplinary program will put Virginia Tech on the map as an innovative leader in Global Change science by focusing on the exciting interfaces among the global threats to environmental health. Unlike other global change programs in the U.S. that focus their efforts on *climate* change, the IGC IGEP will utilize existing strengths in pollution, disease, invasive species, habitat loss, and climate change to determine how these factors interact with one another to influence environmental health and society. In addition, the training program will emphasize the connection between science and society, with specific emphasis on how science can inform environmental policy. Importantly, this IGEP will complement a larger ongoing effort on campus to establish The Center for Global Change which will involve > 30 additional faculty members. In light of the simultaneous effort to launch this new Center, the large number of funding opportunities for the work described in the proposal, and the strong record of funding and collaboration of the core faculty, this IGEP proposal is particularly timely and will raise Virginia Tech's stature as an international leader in Global Change.

We are committed to supporting this interdisciplinary team of scientists as they train graduate students on the exciting frontiers of global change science.

Sincerely,

Eric Hallerman, FiW

for Paul Winistorfer, CNRE

Brenda Winkel, BIO

Lay Nam Chang, COS

for W. Samuel Easterling, CEE
Asst. Dept. Head

Richard Benson, COE

for Nancy Ross, GEO

Loke Kok, ENT

Mark Barrow, HIST

Anne Khademian, SPIA

Jack Davis, CAUS

for Sue Ott Rowlands, CLAHS

Elizabeth Grabau, PPWS

Alan Grant, CALS

for Janaki Alavalapati, FREC

Steve Culver, Assess/Eval

Mary Leigh Wolfe, BSE

Dennis Dean, Fralin LS Inst.