Invasive Pest Prediction and Response
Implementation Plan
August 2009

Membership Roster: Ottar Bjornstad (Entomology and Biology), Margaret Brittingham (Forest Resources), Ann Dodd (Team Sponsor), Arthur Gover (Horticulture), Scott Isard (Plant Pathology and Meteorology), Seogchan Kang (Co-Chair; Plant Pathology), Tracy Langkilde (Biology), David Mortensen (Co-Chair; Crop and Soil Sciences), Gregg Robertson (External Stakeholder; PA Landscape & Nursery Association), Joseph Russo (External Stakeholder; ZedX, Inc.), John Tooker (Entomology), and Ashley Walter (External Stakeholder; PDA)

Executive Summary

A lengthy and thoughtful CAS strategic planning process resulted in a five-year strategic plan spanning 2009 to 2013. This planning process identified five target areas for strengthening, one of which is invasive species prediction and response. These areas were identified because of their importance to sustainable food and fiber production and to the integrity and long-term sustainability of the underpinning ecosystems. Indeed, biological invasions represent one of the top two threats to ecosystem integrity, with an estimated impact of 120 billion dollars annually on agricultural, forest and urban environments. Human facilitated acceleration of non-native species movement coupled with ever increasing demands of our agricultural production systems will only increase the challenges imposed by invasive species.

Penn State has an excellent cadre of scientists and educators working in this important area. For example, in recent years members of this group have: lead a national effort to design and implement a pest prediction and response IT platform; built forensic database that supports identification and global monitoring of major pathogen groups; and received two training grants for graduate students in the areas of invasive plant pathogens and invasive plants. Research from individual labs is nationally and internationally known, and some interdisciplinary programs (e.g., Centers for Infectious Disease Dynamics, Chemical Ecology) are highly visible. However, for the College to position itself as a national/international leader, it needs to facilitate the formation of more such teams. What the group lacks is higher level cohesion, the kind of cohesion that would enable the group to work more comfortably on large, multi-discipline, complex problems. Our implementation plan lays out the following three goals aimed at successfully achieving this goal.

- Stimulate collaborative research and integrated research-outreach
- Integrate web-based information platforms with 21st Century communication technologies to support research, education and extension
- Build institutional capacity by filling critical gaps in expertise

Background on Biological Invasions

Biological invasions represent one of the top two threats to ecosystem integrity and sustainability with an estimated impact of 120 billion dollars annually on agricultural, forest and urban environments. This impact will only grow as trade and human travel increase thereby accelerating the movement of non-indigenous organisms and exotic variants of indigenous ones. One needs not go far from the confines of our campus to put a face on the severity of this problem. Hemlock stands, the state tree of Pennsylvania, are being decimated by the invasive hemlock wooly adelgid, while a similar threat faces mixed hardwood forests as the emerald ash borer invades forests in southeastern Pennsylvania. Mile-a-minute and Japanese stiltgrass, actively invading plants, threaten regeneration of economically important timber species along with plant biodiversity and the communities of organisms they support. At the same time, new insects and diseases threaten the economic viability of crop production in our state. In addition to the introduction and spread of newly introduced organisms there has also been a rapid rise in pesticide resistant genotypes of native organisms. The surge in invasive species and novel genotypes will accelerate as human travel and trade and the evolution of pesticide resistance increase.

The acceleration of invasive species pressure and impacts need to be examined against the backdrop of human population growth of more than 50 million people annually. By 2050, 9.5 billion people will be supported in a world with increasing food scarcity and where bio-fuels will be a critical part of energy portfolio decisions. Increasing sustainable food and fiber production systems will need to be accomplished in the face of increasing pest pressure. The importance of threats to animal and human health by novel pests has been recognized by granting agencies who have experienced significant increases in funding (see Appendix 1) to address the complex problem of invasive species; using integrated methods that bring strong interdisciplinary teams to bear on the problem.

The problem of biological invasions transcends research and outreach needs, and the importance of institutions like Penn State in student-training is being increasingly recognized. As the threat of biological invasion escalates, a disturbing workforce demographic unfolds. A large number of employees in agencies like the Animal Plant Health Inspection Service (APHIS) and the National Park Service (NPS) are mid or late-career scientists and we are not training a sufficient number of adequately prepared young scientists to fill these positions. In recent years, directors of divisions and department within the APHIS and NPS have contacted us expressing concern over the lack of sufficiently trained graduate students in the field of biological invasions. We believe that Penn State can fill this critical role.

Penn State's Capacity to Address Emerging Biological Invasions

Penn State has a breadth and depth of expertise in the field of biological invasions with national and international leaders in most departments in the College of Agriculture as well as in other colleges across the campus. There are over 70 people working on some aspect of biological invasions in Departments as diverse as Crop and Soil Sciences, Entomology, Horticulture, Plant Pathology, Forestry and Bio-Systems Engineering in CAS and outside the College in Biological Sciences, Geography, Landscape Architecture, Meteorology and Statistics. However, while we have an excellent cadre of

research and outreach scientists, a higher degree of integration across these disparate disciplines is needed to address larger scale more complex biological invasion problems. It is also the case that to effectively compete for external funding, we must accomplish a greater degree of integration across disciplines. We believe there is a pressing need to bring experts together in a stimulating environment that will lead to true interdisciplinary work and major funding. It is clear that such an effort can be lead by scientists in CAS and that such a thrust will benefit from involvement of scientists in other Colleges, as well as state and federal agencies and those in the private sector. Those people are here; we have an incredibly strong cadre (this word is used a lot) of scientists. What we are lacking is a higher level of integration. Our proposal outlines three goals that address this important mission, along with an associated set of enabling actions.

Explicit Goals to Enhance Invasive Pest Prediction and Response at Penn State

Goal 1. Stimulate collaborative research and integrated research-outreach

Background: Penn State has researchers with a strong record of invasive species-related research across a range of research areas (from economics and management to pest biology, theoretical modeling and ecological and evolutionary studies of impact) and species (from insects to mammals to weeds and disease). We need a mechanism to promote collaboration among these groups if we are to effectively utilize this disparate yet complementary resource to solve complex problems of national and international importance, encourage new and innovative collaborations, and work effectively with federal and state agencies, industry, and non-governmental organizations which also work on invasive species issues in Pennsylvania.

Actions and resources: We propose 3 actions to achieve this goal.
1) *Create an Invasive Species Liaison Position* to facilitate the coordination of invasive species research activities within the University and amongst external stakeholders. The liaison should have outreach responsibilities, to maintain technical credibility with the stakeholders, and use outreach opportunities to promote the capabilities of the College. The metric of success could largely be defined by the number of contacts they establish and maintain, and by 'units of information exchange' between college personnel and stakeholders, participation in Extension meetings and workshops, and funded initiatives. Initial implementation would be solely by the College, working to identify College and University expertise, and partners and resources in government agencies, NGO's, and industry. In time, the CAS liaison could work with a State-funded liaison as part of the function of the Pennsylvania Invasive Species Council and aid in the pursuit of external funding opportunities.

2) *Promote communication among diverse groups*, such as researchers from different but complementary fields, governmental organizations, and outreach through shared conferences, seminar series and workshops. This is critical if we are to develop innovative interdisciplinary research, training and research-outreach programs. This action could be achieved with minimal investment, requiring logistical and planning

support. The faculty and staff in the Center for Infectious Disease Dynamics, Penn State Institutes of Energy and the Environment, the Chemical Ecology Group, ITS, and EMS could provide valuable contacts and support for this venture.

3) *Allocate seed funds to facilitate the creation of interdisciplinary research groups, and integrated research-outreach projects*. Priority will be placed in initiatives that involve cross-departmental and/or cross-college collaboration, and that have specific outcomes (e.g. external grant proposal, development of new outreach tool) and a timeline for its attainment. The Universities Social Science Research Institute has an existing framework that may be used as a model for this initiative. The College of Agricultural Science's existing internal seed funds program could be modified to achieve this goal. The seed money will support the development of research programs and collection of pilot data, and it is anticipated that these Collaborative programs will successfully obtain external funding.

Anticipated impact: Integration of Penn State's current research strengths and communication and collaboration with external agencies and outreach programs to conduct key integrative research, develop and implement management plans, and communicate these recommendations to stakeholders and the public. Innovative and directed collaborative research efforts will enhance Penn State's standing in this field. Formal communication between basic researchers, government agencies and outreach organizations will benefit all those involved in invasive species research, prevention, detection, and management.

Goal 2. Integrate web-based information platforms with 21st Century communication technologies to support research, education and extension

Background: Penn State has established itself as a leader in development and deployment of information technology (IT) platforms that support pest identification, risk prediction and response (see Appendix 2). These platforms and associated databases have international, national, and state-level focuses and have been produced via collaborations with state and federal agencies, private industry, and other universities, primarily with funding from USDA-AFRI Plant Biosecurity grants. To maintain Penn State at the forefront of the effort to merge IT with research and outreach programs in Pest Prediction and Response (PP&R), the College of Agricultural Sciences now needs to capitalize on the new ways that people, especially the younger generation, are communicating. We must recognize that the new technologies, such as social networking, are quite different from those traditionally used by personnel in the College for scientific research, education, and extension.

We must further develop our strength in IT platforms for PP&R by exploring ways to expand the PA PIPE system to include other important pest species as well as beneficial organisms, and to interface this and other existing PP&R IT platforms at Penn State with social networking technologies. Citizen scientists ranging from school children, Master Gardeners, and commercial growers offer millions of eyes and hands for detecting and responding to pathogens, weeds, and arthropod pests. We need to use new social

networking technologies to engage these potential contributors throughout the state and make them stakeholders in agriculture security and the College. We urge the College to take the following judicious action to position PSU PP&R teams to successfully compete for federal and state funds, such as those in the "Plant Pest and Disease Management and Disaster Prevention" section of the new Farm Bill (Appendix 1). In addition to enabling Penn State to capture substantial federal and state PP&R funding, the development of web-based platforms that meld state-or-the-art IT tools with social network communications technologies to engage citizen scientists will increase appreciation by Pennsylvanians for the goals and values of the College and lead to increased student enrollment in the College.

Actions and resources: We propose four actions to achieve this goal.
1) *Create an Invasive Species Prediction and Response (ISPR) IT latform Coordinator Position* to expand the involvement of faculty, staff and state and federal agency scientists in PA PIPE applications development. The metric of success could largely be defined by the expanded involvement of research and outreach scientists in expanding the utility of PA PIPE. In the end, the goal of this position is to enhance the end-user utility of this web-based delivery of invasive pest information.

2) *Extend existing PA PIPE activities to other important pest species and beneficial organisms* through engagement of existing PSU faculty and researchers. Currently, state invasive species specialists are tracking the presence of invasive species and their relative abundance. PA-PIPE could be the portal through which such data is made available to land managers, researchers and outreach specialists. We also have research underway in CAS that generates data that could be useful to land managers but that is currently not readily accessible. Extending the Soybean Rust IT framework to other relevant invasive species was an area identified as "high priority" by our committee, particularly by our outside stakeholders.

3) *Coordinate the incorporation of new social networking technologies into the PA PIPE and other PSU ISPR IT platforms.* Citizen scientists ranging from school children, Master Gardeners, and commercial growers offer millions of eyes and hands for detecting and responding to pathogen, plant and arthropod pests. Social networking technologies and strategies will be identified that engage these potential data contributors.

4) *Develop targeted educational programs to "enable" citizen scientists to collect meaningful invasive species data and to use the ISPR IT.*

Anticipated impact: The ISPR platform will make it possible for outreach and campus-based educators to access near real-time data on a range of invasive species for use in a range of educational programs. Temporally dynamic occurrence and abundance mapping will enable researchers to use data for theory and management applications development while practitioners will be provided data that will aid in making informed invasive species management decisions.

Goal 3. Build institutional capacity by filling critical gaps in expertise

Background: Penn State has a range of faculty with strong research programs in the ecology and evolution of invasive species and the ecological and evolutionary implications of their management. We believe the actions laid out in the Goal 1 will help organize work underway in CAS and in related colleges. As a result of those actions, we anticipate identifying several critical faculty positions that will help foster cohesion among scientists in this area. We therefore see Goal 1 being a necessary prerequisite to identifying key new faculty positions that will join an already strong group here in CAS. There is one position that was clearly identified as a need at this time.

Actions and resources: We propose two actions to address this goal.
1) *Hire a broadly trained plant disease epidemiologist* to work on invasive pest prediction and spread. Ideally, the candidate would be able to transcend pest groups to also address the "epidemics" of plant and insect spread and establishment. Hiring such a person is a high priority for the Department of Plant Pathology and is seen as a critical step in building institutional capacity in invasive species prediction and response.

2) After going through the four steps outlined in Goal 1, *three additional faculty positions will identified to build group cohesion and research capacity in the area of invasive species prediction and response*. Particular attention will be paid to positions that will leverage on and enhance synergistic among an already strong group of scientists working in this area.

Anticipated impact: Additional faculty positions will build on an already strong base within our college and in the Departments of Biology and Geography. There is a pressing need for research that provides a greater understanding of the plasticity of invasive species and that assesses the ecological and economic impact of the invader and its management. We are also encouraged by the expanding funding possibilities in this field (Appendix 1). We are confident that rather modest investments in human resource capacity will position CAS to be a national leader in this field.

Appendix 1. Potential External Funding Sources

Both USDA and NSF have a number of funding programs that support research, education and/or outreach activities. In this section, a new funding source, which resulted from the new Farm Bill, is described, as this five-year funding can be a significant source of support for the initiatives proposed in Section 5. Section 10201 ("Plant Pest and Disease Management and Disaster Prevention") of the Farm Bill specifies that Commodity Credit Corporation (CCC) funds be made available (starting with $12 million in FY 2009, $45 million in FY 2010, and $50 million in FY 2011 and thereafter) to integrate and coordinate plant pest and disease management and disaster prevention activities. The USDA will partner with States, industry, the public, and its peer and sister agencies to safeguard and protect the U.S. plant and agricultural health better through this five-year investment. Six major goals include:

- Enhance plant pest/disease analysis and survey
- Target domestic inspection activities at vulnerable points in the safeguarding continuum
- Enhance and strengthen pest identification and technology
- Safeguard nursery production
- Conduct outreach and education to increase public understanding, acceptance, and support of plant pest and disease eradication and control efforts
- Enhance mitigation capabilities

Appendix 2. Recent and Current Projects in Pest Prediction & Prevention

A2.1. *Phytophthora* Database (3/1/05-2/28/08; $950,000 from USDA-NRI): To enhance the ability to detect, diagnose, monitor, and manage *Phytophthora* diseases, this project aims to establish an internet-accessible database named as the *Phytophthora* Database (PD, www.phytophthoradb.org). The PD catalogs genetic and phenotypic diversity of *Phytophthora* species in a format that can be easily accessed, utilized, and compared by the global community of plant health professionals, and also provides an array of molecular diagnostic tools. This project established a baseline for monitoring the emergence of new/foreign pathogens and helps us track the movement of *Phytophthora* via agricultural trades. The PD currently has more than 250 registered users from 40 countries.

A2.2. Global *Phytophthora* Network (3/1/08-2/28/11; $999,917 from USDA-NRI): This project will enhance global human capital in studying and managing new or reemerging *Phytophthora* diseases. The GPN is being built by weaving together the following threads: (i) a globally-linked network of researchers on *Phytophthora*; (ii) the *Phytophthora* Database; (iii) Geographic Information Systems (GIS) tools supporting the monitoring and visualization of *Phytophthora* species/populations and diseases across environmental, geospatial and temporal contexts; and (iv) global agronomic, geospatial and environmental databases and weather modeling tools to support the development of disease forecasting models.

A2.3. Aerial dispersal of soybean rust spores (7/1/04-6/30/08; $900,000 from USDA-NRI): The team conducted research on the effect of solar radiation and its UV component on the viability of soybean rust spores in Paraguay during winter 2005. The relationships established in this work were incorporated into the aerobiology model that forms the basis of the *ipm*PIPE (see below). Output from the model helped guide scouting efforts for the disease during autumn 2004 and the summers 2005 and 2006. Many millions of U.S. soybean acres that would have received at least one fungicide application for soybean rust remained untreated in 2006 due to information disseminated through the *ipm*PIPE website. This project has been heralded as a positive response to a national biosecurity threat. All co-PIs were members of the soybean rust team that was awarded the Secretary of Agricultures Honor Award in 2006.

A2.4. IPM-Pest Information Platform for Extension and Education (9/1/05-12/31/08; $950,000 from USDA-APHIS and USDA-CSREES): The *ipm*PIPE (www.sbrusa.net), originally built in response to the soybean rust invasion of North America, has facilitated cooperation among researchers, field specialists, and regulators via a cyberinfrastructure to effectively manage this devastating pathogen in the US, Canada, and Mexico. The USDA estimated that the coordinated framework approach, coupled with *ipm*PIPE, saved the US soybean growers between $11 and $299 million in 2005 at a low cost of $2-5 million. The underlying cyberinfrastructure was so effective that the USDA has adopted it as the new paradigm for Integrated Pest Management (IPM). The *ipm*PIPE supports observation networks, diagnostic labs, data management, modeling, interpretation, and the dissemination of timely information to help farmers combat diseases and insect pests. Field observations, channeled through standardized Internet portals into a national

database, are immediately available to researchers throughout the country who add value to the observations through modeling and analysis and communicate interpretations, management guidelines, and other materials to growers and industry agents through the web.

A2.5 National Needs Fellowship Program in Invasive Plants (9/1/07-8/30/12; $172,000 from USDA-CSREES): This training program will prepare doctoral students to fill the critical gap in quantitatively trained scientists who also capable of field site assessments and management options for invasive plants.

A2.6. National Need Fellowship in Agricultural Biosecurity (8/1/05-7/31/10; $138,000 from USDA-CSREES): The goal of this PhD training program is to raise human capital for agricultural biosecurity through research projects related to this topic. The fellows are trained in one or more of four areas: aerobiology, fungal biology, bioinformatics, and pathosystems management. One area of particular emphasis is information science. The highly integrative and multidisciplinary nature of the research projects the fellows are working on provides an excellent opportunity for systems approach-based training.

A2.7. The Incursion of New Wheat Stem Rust Races into the United States: Preparation thru Research, Education & Extension (3/1/2009-2/28/1011; $999,990 from USDA-NRI). The goal of this Integrated Biosecurity Project is to build on this existing infrastructure to improve the knowledge base, sampling strategies, educational materials, and rapid communication networks necessary to provide U.S. growers with effective in-season management of stem rust in wheat and barley. We are converting the existing infrastructure to a "state-of-the-art" Wheat Stem Rust Information Technology (IT) platform over the next two years, hopefully prior to the incursion of the new *Pgt* races into the U.S. This IT platform for wheat stem rust will have functionality similar to that of the USDA Integrated Pest Management, Pest Information Platform for Extension and Education (*ipm*PIPE), with a design that reflects the current USDA ARS Cereal Disease Laboratory-led surveillance network and the needs of specialists, wheat and barley producers, and other stakeholders to rapidly detect and respond to a Ug99 stem rust incursion.