**Theme, Vision, and Goals**

The US faces a key need for next generation biodiversity researchers. For understanding emerging infectious diseases, detecting and stopping invasive species, managing natural resources, and understanding how to conserve biodiversity in the face of anthropogenic change, we need biologists trained in a wide array of skills (Tewksbury et al. 2014). However, our training efforts often result in a relative handful of researchers with deep taxonomic and evolutionary knowledge of one group but little training in how to apply it, or workers trained in details of resource management but without sufficient depth of knowledge of evolutionary or ecological contexts. Regardless of training path, many graduates lack skills in the latest technology revolutionizing fields, ranging from next generation sequencing abilities allowing detection of organisms from wisps of DNA in a stream or sequencing entire viral genomes in a day, drones allowing remote sensing of biodiversity data, and geographic information systems to allow precise mapping and correlation of abiotic factors with responses of organisms. Moreover, none of our training of potential leaders in these tools covers necessary skills such as project management. Our training is often focused on creating new academics: even though a substantial number of graduates go on to non-academic fields, these is often described as “alternate academic” paths, and programs do very little to train students for them.

Our strategy to remedy this is a new program that capitalizes on the University of Tennessee, Knoxville's academic expertise while also engaging with local and national partners. The program covers four modular areas. The first three include **1)** core biology training: areas such as ecology, evolution, genetics, and especially natural history; **2)** technological training: remote sensing, genomics, GIS; **3)** leadership and management training. The core biology training builds on existing courses but will also feature two-week intense field courses. The technological training will largely be delivered in workshops. Our faculty already offer a few workshops that can draw interest from hundreds of applicants; by streaming these online, we can reach many more trainees than the core set of students supported by the program. Tutorials and field courses also offer a mechanism for long term sustainability of this initiative through participant fees. For vocational training we will capitalize on relevant courses in project management and team building, including coordinating with colleagues on the creation of new courses. In modular area **4)**, trainees will participate in at least one internship with our partners, which will help build their professional networks and expose them to the management of concrete issues. Throughout the life of the grant, integration with our external partners will help us tailor training to meet key needs they identify. The overall goal is to graduate Masters and PhD students with the intent of pursuing careers in business, NGOs, or government: unusually for many biology graduate programs, especially those at liberal arts colleges (like that of one of our three collaborating departments), an academic career will be not be the target for our students upon entry, and we expect few to go down that path.

UT Knoxville is the ideal location to establish such a program. For biodiversity experts, we are already a key destination given our high regional biodiversity and existing groundwork to map it (e.g. All Taxa Biodiversity Inventory, which has mapped 19,000 species in Great Smoky Mountains National Park), research collections (TENN Herbarium housing vascular plants, bryophytes and fungi, UTK Fish Collection, UTK Caddisfly Collection) and faculty-led courses about fish, fungi, plants, reptiles, amphibians, mammals and invertebrates. We have a tradition of collaboration with, and placement of graduates in, federal and state agencies, and NGOs such as The Nature Conservancy and the Tennessee Clean Water Network. Our technological skills are at the cutting edge, with expertise in environmental DNA monitoring, high performance computing, next generation sequencing, and use of drone and satellite imagery for addressing biological questions.

*Context for added value*

Our programs track outcomes: for example, we have tracked placement of EEB PhD and Masters students for the past 16 years, and know placements for 127 of 135 graduates of that program. This baseline data will be useful in allowing us to measure the impact of this program. It also allows us to integrate program participants into alumni networks, especially with alumni outside academia. These data suggest that for our programs, academia remains the default outcome, with 83% of EEB PhD graduates either in a faculty role or in some other academic research position (often postdoctoral positions, especially for recent graduates, with the intention of moving on to faculty positions) and 50% for Entomology and Plant Pathology.

*Goals*

Our project has three main goals:

1. Produce STEM professionals who are interdisciplinary, technically savvy, and professionally literate.
2. Advance biodiversity research
3. Generate knowledge about innovations in graduate education approaches

In addition to published work on key needs (Tewksbury et al. 2014), we have surveyed potential employers for biodiversity STEM graduates for needed skills. Repeatedly, they indicated that knowledge of geographic information system software, experimental design, technical writing skills, and detailed expertise in one or more taxonomic groups was key.

**Education and Training**

The traineeship model has four main components: 1) core coursework in ecology, evolution, statistics, GIS, and related areas, 2) two-week field courses focused on particular groups of organisms, 3) intensive workshops in skills, and 4) internships. The **core coursework** builds on existing UT courses spanning three modular areas. The core biology is supported by traditional graduate student offerings across departments. Existing technological training courses include ENVE 561 - Climate and Environmental Informatics, GEOG 517 - Geographic Information Management and Processing, and EPP 622 – Bioinformatic Applications. Courses in the third area, management and assessment, include EDAM 560 – Grant Writing and Project Management, ENMG 536 - Project Management, and ENMG 541 - Managing Change and Improvement in Technical Organizations.More targeted graduate courses depending on the needs of the trainees may also be utilized. Capitalizing on established courses helps make the program more sustainable after its funding runs out and exposes trainees to students and instructors from a variety of perspectives. **Field courses** are key ways to promote learning (McLaughlin and Johnson 2006) and UTK faculty have experience teaching in field courses for a variety of organisms. **Skills workshops** will be available online (through streaming and materials), following the models used by O’Meara (at several NIMBioS tutorials on computing, phylogenetics, R, and genetics, as well as an NSF CAREER grant-sponsored course) and Staton (tutorials in next generation sequencing and bioinformatics as well as being a certified Software Carpentry (Wilson 2006) instructor). Assessment of domain knowledge at the beginning, completion, and a year after each field course and skills workshop will help highlight effective strategies and long term impact. **Internships** will allow students to build networks outside academia and learn about the skills necessary for careers at places such as federal and state agencies, environmental consulting agencies, and more.

*STEM graduate population that will be served:*

This grant will serve four audiences. The first is funded trainees: 15 PhD or Masters students funded with $30K stipends (plus tuition and benefits) for two years each. These students will make up the core of the program. The next tier are other UTK graduate students in the affiliated EEB, FWF, and EPP departments as well as students in related groups such as Earth and Planetary Sciences, Genome Sciences and Technology, and Geography. These students will participate in one or more of the field courses or skills workshops; over the five year life of the grant; we anticipate training between 30 and 100 students. The third tier consists of external participants who would attend in person a field course or skills workshop, pay some tuition/fee but have this cost supplemented by the grant. These participants could be academics, especially graduate students, from other institutions, land managers, biocontrol workers, agency employees, and other non-academics. These experiences would deepen connections between the program and the broader community, and importantly expose core and affiliate students to people successfully pursuing careers outside academia. The fourth population is people remotely making use of teaching materials. The audience size for this is uncertain, but available metrics indicate it could be quite large: NIMBioS online video tutorials can have hundreds of views, and O’Meara’s course website for his NSF-sponsored flipped phylogenetics methods course, which was launched in January, 2016, has had 6,136 visitors to date from 94 countries.

*Internships*

A major aspect of training is placing students in internships. We have coordinated with the following organizations for potential internships for our students:

**TABLE OF INTERNSHIPS**

**Major Research Efforts**

There will be three areas of catalyzed research. First will be research performed by students while studying at the University, both while funded as part of this grant and, for PhD students, while funded from other sources. Second will be research enabled through cross-disciplinary interactions fostered through this project. Third will be published research based on assessments of the program.

Students in this program will pursue research-based dissertations in areas relating to modern biodiversity. Most notably, the world faces a biodiversity crisis: human activities are driving some species to extinction, invasive species are a major economic risk ($70.4 billion for the agriculture in the US alone (Paini et al. 2016)), and the skills to identify critical species are being lost (Agnarsson and Kuntner 2007).

**Broader Impacts**

It is increasingly recognized that graduate programs in sciences should not focus on just churning out future faculty (Nature Editorial Board 2014), but few are configured for broader career outcomes. This project builds connections between graduate students and professionals outside academia while training students for a wide variety of positions focused on biodiversity. The addition of necessary practical skills such as project management and assessment will position graduates to be strongly competitive and ultimately more successful in industry or academia. The open nature of the training also pushes scientific knowledge out into the public domain where professionals can learn from it, fulfilling a classic role of land grant institutions. Sponsored student research projects will span a variety of biodiversity questions, likely ranging from alpha taxonomy to modeling population movement with climate change to studies of urban ecology.

On a broader scale, despite some clear advantages of academia as a way of training more academics for knowledge creation and dissemination, it is increasingly being recognized as problematic. It often involves great financial uncertainty until people enter their late twenties or early thirties, and generally requires a willingness to move away from one’s community for increasingly elusive employment. Graduate programs are paying increasing amounts of attention to this, and may now include a few seminar speakers from outside academia, a discussion group on alternative careers, or similar small scale programs. Our approach is radically different: with this program, the “alternate” career is academia – our goal is to get our students out into the world working with real world biodiversity questions. Both the academic and non-academic paths have great value, but the latter needs much more emphasis. The triumphs and failures of this program, which will be communicated throughout the grant, will help be a prototype other programs can adopt when they choose to bring the same rigor and attention to non-academic paths as they do to academic ones.

Finally, this is an unprecedented time of threats to biodiversity. We desperately need more research on threats and how to mitigate them, but we also need muddy boots on the ground to implement best practices. Students from our program will have deep knowledge of biodiversity, ecology, and evolution, while also having skills in project management and contacts with NGOs and private companies required to effect real change.

**Organization and management**

The faculty involved in this grant as PIs and Co-PIs will comprise the leadership team. They already are fairly well-connected (Kwit spans two involved departments, O’Meara has served on committees for PhD students of Moulton and Kalisz, Staton, Kalisz, and O’Meara are all affiliated with NIMBioS, and so forth). O’Meara as PI will help ensure the project meets its goals, but the team member who will serve ideally as a bridge between communities, both in and off campus, will be Kwit. Kwit’s recent research spans areas from warbler winter habitat management in the Bahamas, bioenergy sustainability of switchgrass as a biofuel crop, oak savanna restoration, climate change vulnerability indices for conservation, and animal-mediated seed dispersal, and he is a joint appointee in the Department of Forestry, Wildlife, and Fisheries in the College of Agricultural Sciences & Natural Resources and the Department of Ecology and Evolutionary Biology in the College of Arts and Sciences, both at the U. of Tennessee. He thus would be the ideal resource for students in this program, and will be receiving a month of summer salary per year to enable his time to be used for this. Note that while is his currently an assistant faculty member, he is expected to receive tenure by the start date of the grant. We envision hiring a half time staff person to serve as Project Coordinator. This person would report to Kwit and O’Meara, and would be responsible for overseeing steady progress of the students and handling connections between them and internship opportunities. Evaluations will be handled by East Main Evaluation and Consulting, LLC: Dr. Barbara Heath will be leading this group, but may be assisted by staff or interns within her group.

A sense of community will be fostered organically through overlapping courses and workshops taken by students and taught by faculty. We will also have two social gatherings per year: one in February at the time of recruiting, and one at the end of the academic year. These will feature core students and their families, recruited applicants (in Feb.), the leadership team, and other members of the involved departments. We will also create a web site and chat room for the project. The chat room especially will allow participants to discuss issues as they arrive, celebrate successes, and ask for advice. The technology we would use today is a service such as Slack or Gitter; given the anticipated start date for the grant approximately 1.5 years in the future, these particular services may have been replaced but we will use the equivalent at that time.

Students in our program will be full members of one of the three collaborating departments. Our plan is to set a floor such that each department receives at least 25% of all students and thus have buy in. We will only admit students if we can assure them of funding until graduation (as long as they meet adequate progress guidelines). For Ecology & Evolutionary Biology, this means that after their NRT funding expires Masters and PhD students will continue on guaranteed TA or RA lines, until graduation. For Entomology & Plant Pathology and Forestry, Fisheries, & Wildlife, which have few TA lines, most admitted students will be Masters students expected to graduate in two years unless their advisor has other sources of funding.

***Coordination with administrators***

A training grant will fail without institutional support. At the level of department heads, we have one department head as a Co-PI on the grant, an associate head as PI, and have had frequent contacts in developing it with heads of the other two departments (with particular concern for how participation in this grant affects tenure considerations for Co-PIs who are junior faculty). We have also met with Associate Dean Brothers regarding this grant and will continue to consult with him moving forward.

We will coordinate with higher level administrators in two ways. The first is informal: we will invite them to our two annual social events so they can form connections with our students and our external partners. The second is through annual, public reports describing grant progress and institutional successes and deficiencies that would be forwarded to the Dean of each involved College. For example, retention data are important in assessing how the program is working: it is a waste of resources to train a student and have her or him leave the program due to some program deficiency. The University as a whole does not track this for graduate students; our involved departments do, but this is something that should be changed on an institutional level.

***Project roles***

* *Program coordinator*: half time position for a staff member. She or he will be involved in matching students to internships, tracking progress, and preparing reports. A half time position should be adequate for the program’s scope, plus promotes sustainability in the future.
* *PI O’Meara*: He will oversee the project to make sure it delivers on its goals, as well as teach in workshops. His involvement is part of UT’s investment for sustainability.
* *Co-PI Kwit*: He will be the key contact person for students and external members. He can fluidly move between the worlds of academia and applied work.
* *Co-PIs Stanton, Moulton, and Kalisz*: They will teach in workshops. Their involvement is part of UT’s investment for sustainability.
* *Affiliate faculty*: Faculty who seek to enroll students through this program will have to first go through a training session on alternative academic careers and cross-mentoring. The need to do this before students can be accepted will be an inducement to widespread training in this area.
* *Core students*: These will be the funded students who will engage with the program, its training, and internships.
* *Affiliate students*: These are other students at the U. of Tennessee who will take classes through this NRT.
* *External students*: These are members of the community who would take workshops through the NRT.
* *External internship mentors*: Partners at local companies, NGOs, and government agencies who will host students.
* *East Main Evaluation and Consulting, LLC*: Assessment of project outcomes.

***Sustainment plan***

Sustaining the program after the conclusion of NSF funding is key. First, the involved departments will continue funding the NRT trainees in the same manner as regular trainees, assuming adequate progress, once the grant ends. The long term vision is that the this new traineeship gradually becomes integrated into regular graduate training: as faculty and students see the benefits of biodiversity training for careers outside academia, cultural expectations of the programs will shift. In the same way training for academic careers is currently the default, and which thrives despite lack of NSF funding explicitly for this, we expect our training model to diffuse through the relevant programs. Similarly, tasks that will be undertaken by the Program Coordinator to start will devolve to the graduate coordinators of each department.

**Recruitment, Mentoring, and Retention**

This NRT has a two-fold strategy to recruitment and retention: providing student access to the program, ensuring that potential graduate students from all walks of life are aware of the opportunity to apply, and creating an environment of inclusion with enrichment experiences to maintain retention and facilitate attainment of students’ goals.

***Recruitment:*** This NRT program will work closely with UT’s Graduate School, which supports 55 doctoral degree and 76 master’s degree programs, to recruit a diverse population of students. We will join Graduate School representatives as they participate annually in graduate school fairs across the Southeast and at national conferences such as the annual Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) conference, which has 3,600 attendees from a wide variety of backgrounds, as well as professional conferences. In addition, we will provide printed and online promotional materials about the NRT Traineeship, which will be disseminated in these venues and others. Our focus on training students for careers outside academia, which can result in higher starting salaries (\_\_\_\_\_\_) and far less uncertainty in career outcome and locale after graduation (\_\_\_\_), will help broaden our set of participants (\_\_\_\_\_\_). We will also leverage the Graduate School’s recruitment activities that focus specifically on underrepresented students, such as campus visits from TRIO, McNair, and NSF LSAMP programs throughout the region. Finally, we will work with colleges throughout UT that engage in decentralized recruitment activities taking place at the departmental level. Each year, we will sponsor two major events for students and prospective students, one during a graduate recruitment weekend in early spring, focused on prospective students, and the other at the end of the spring semester, focused on celebrating graduate students’ progress.

Institutional support will come from Associate Dean of the Graduate School Ernest Brothers, who is an expert in graduate student diversity and mentoring. He recently presented a workshop, “Diversity and Mentoring in Academia,” to Oak Ridge National Laboratory and a workshop, “Strategies for Mentoring Diverse Graduate Students and Faculty” to UT’s Psychology Department. He will present similar workshops for our faculty, to set the stage for a welcoming environment upon NRT Trainees’ arrival in Knoxville. Brothers is on several boards related to diversity and graduate student training, including UT’s NIH-funded Program for Excellence and Equity in Research (PEER).

***Mentoring and retention*** will build on the strengths of our programs. For example, EEB has tracked long-term placement of our graduate students over the past 16 years; out of the Masters students, 27 (52%) have gone on to careers outside colleges and universities, at jobs ranging from the US Forest Service to education coordinator at the Jackson Zoo to program director at the New York City Parks Department to high school biology teacher. The EEB department has also created its own tracking software to monitor grad student progress towards degree and to automatically highlight potential issues while building up a long term, secure, database of progress and outcomes. Data-intensive approaches such as these can identify problems early while also making programmatic assessment more rigorous for reports to grant agencies or higher administrative levels within the University. Core trainees will be mentored through standard committee structures but also through annual meetings with the trainee program coordinator (one of the core faculty). The initial meeting will involve the creation of an individual development plan with concrete goals; this plan will be re-evaluated every year. Students will also be mentored through the informal networks fostered by their internships in their second year of grant funding.

Co-PI Kwit will oversee Trainees’ mentorship and mentoring activities to be developed. One of these activities is a weekly discourse session, modeled on a PEER initiative to increase the number of exceptional underrepresented students graduating with doctoral degrees in STEM disciplines at UT. Another activity will help students develop an individual development plan and monitor their progress toward accomplishing their goals.

Retention: We will create a community of scholars within NRT cohorts and connect students with other programs at UT. The goal is to create experiences that further each student’s professional aspirations. We will leverage existing resources, such as UT’s Multi-Cultural Graduate Student Organization, which connects members of underrepresented groups across campus, to help students connect with others. We hope to improve on UT’s current graduate student retention rate, which is \_\_\_\_, by increasing that rate to \_\_\_ in our three disciplines. Working with the Graduate School’s new customer relationship management system, we will be able to identify where students were recruited, and when they applied, were accepted, enrolled, and matriculated. Such a system enables the NRT program to automatically respond to students, providing immediate feedback.

**Performance Assessment / Project Evaluation**

External evaluation will come from East Main Evaluation and Consulting, LLC, a group with experience with evaluating NSF-funded and other projects, including serving as the external evaluator for the iPlant / CyVerse projects ($94.1M in total). The evaluation of this Research Traineeship Program will follow a process and outcome framework. This evaluation approach will provide a comprehensive model to analyze the project activities and gather data for the program effects. Within this process and outcome framework, a logic model will be developed in coordination with the project team prior to submission of the full grant proposal and will be used to represent the sequence of steps between program services and outcomes. Key metrics will be annual progress towards degree, trainee satisfaction, and knowledge assessment before and after key training activities such as workshops, courses, and internships. Internship hosting organizations will be asked for their perspective on the performance and marketability of trainees through this program (as has been done for undergrad internships, i.e., Gault et al. (2010)) as well as qualitative impressions. This will allow fine tuning of training while the first cohort of students is still progressing through the program. We will also survey students after graduation, both for placement and to learn their impressions of the efficacy of the training. Competencies assessed will include biological domain knowledge, understanding of relevant technologies (such as modern sequencing methods and use of remote sensing data), and competency in leadership and management skills required for successful careers.

We have three goals for the assessment. The first goal is to allow data-driven improvements in the program overall: adjustments in recommended timing of events, discovering which internships provide the best outcome, changing the mentorship models. The second is to provide data back to NSF in our annual reports to allow them to adjust the NRT program as a whole. Finally, we hope the training model we develop will become a prototype for others to adopt. These adopters could be other programs within the University that seek to combine scientific training, leadership skills, and experiential learning, as well as programs located in other biodiversity regions. To help with this goal, all reports will be posted publicly, and publications for peer review will be prepared and submitted to disseminate the process and related findings of the training program.

**Recent Student Training Experiences**

Over the past five years, PI O’Meara has had four graduate students in his lab. All are still currently enrolled: two are on schedule to receive their PhD in ecology and evolutionary biology as well as a Masters in statistics this semester, another recently received a DDIG award and is on track for graduation on schedule, and a fourth recently took his PhD qualifying exam. The two students planning to finish this semester have decided to pursue careers outside of academia, and enrolled in and successfully completed a program to earn a Masters in statistics while in a PhD program with this intention. They both had internships at the Tennessee Valley Authority (one received an offer of a job once she graduated), and one has also interned with our athletic department analyzing academic progress of athletes. Half of O’Meara’s students identify as women, and one identifies as Hispanic. O’Meara also serves on approximately one-third of graduate student committees in the Ecology and Evolutionary Biology department and has also served on student committees in Entomology, Earth & Planetary Sciences, Microbiology, and Genome Sciences and Technology. O’Meara has also served on EEB’s graduate admission committee and now is associate head for graduate affairs in the department; as part of this, he has run training for graduate students in grant writing. As associate director for postdoctoral training for NIMBioS, he has also organized training sessions for postdocs pursuing careers in biology, math, and statistics.

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