

PI: Brian O'Meara, Dept of Ecology and Evolutionary Biology

Summary Title: Next generation biodiversity training

Priority area to be addressed: Other: Biodiversity training for diverse applications

Names of core participants: Brian O'Meara (Ecology & Evolutionary Biology), Charlie Kwit (EEB & Forestry, Wildlife, & Fisheries), John Moulton (Entomology & Plant Pathology), Meg Staton (Entomology & Plant Pathology), Susan Kalisz (EEB), Barbara Heath (external evaluator, EMEC LLC)

Overarching theme, vision, and goals of the proposed NRT: 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 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.

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.

Traineeship model, its components and how they are integrated with NRT research activities: 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.

The 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.

The novel, potentially transformative research that the NRT will catalyze: 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: how will both the training components and major research efforts contribute broadly to the achievement of “societally relevant outcomes”: 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.

A description of the recruitment, mentoring, and retention plan: Recruitment will happen via outreach at traditional scientific conferences, social media, and online forums. We will also do targeted outreach to build a diverse applicant pool, through attending 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 utilizing the long standing relationships between UT and various HBCU and other MSI schools. The open nature of our materials will also result in widespread exposure of our program to potential applicants and their mentors.

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. 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.

Plans for assessing the success of the training, including specific expected competencies and outcomes: 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.

UT internal benefit: This grant fosters interactions and training across three departments and two colleges. It builds on existing infrastructure (courses, biology field station, resources for web casting and hosting tutorials). The grant's open dissemination of training materials and assessment positions UT as a leader in metric-based education that serves the citizens of Tennessee and the US. Finally, this will train students for a variety of positions, filling key needs in the state and promoting successful graduate placement overall, which an action priority of VolVision 2020.

References:

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Biographical Sketch

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Professional Preparation

Undergraduate

Harvard University	Cambridge, MA	Biology	B.A., 2001
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Graduate

U. of California, Davis	Davis, CA	Population Biology	Ph.D., 2008
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Appointments

August 2016-present	Associate Director for Postdoctoral Training, National Institute for Mathematical and Biological Synthesis (NIMBioS), Knoxville TN
August 2016-present	Associate Head, Department of Ecology and Evolution University of Tennessee, Knoxville TN
August 2015-present	Associate Professor, Department of Ecology and Evolution University of Tennessee, Knoxville TN
August 2009-2015	Assistant Professor, Department of Ecology and Evolution University of Tennessee, Knoxville TN
Nov. 2007-2009	Postdoctoral Fellow, National Evolutionary Synthesis Center

Five Most Relevant Products

O'Meara, B. C., S. D. Smith, W. S. Armbruster, L. D. Harder, C. R. Hardy, L. C. Hileman, L. Hufford, A. Litt, S. Magallon, S. A. Smith, P. F. Stevens, C. B. Fenster and P. K. Diggle (2016). "Non-equilibrium dynamics and floral trait interactions shape extant angiosperm diversity". In: *Proceedings of the Royal Society of London B: Biological Sciences* 283:1830.

O'Meara, B. C. and J. M. Beaulieu (2016). "Past, future, and present of state-dependent models of diversification". In: *American Journal of Botany*. 10.3732/ajb.1600012.

Zanne, A. E., D. C. Tank, W. K. Cornwell, J. M. Eastman, S. A. Smith, R. G. FitzJohn, D. J. McGlinn, **B. C. O'Meara**, A. T. Moles, P. B. Reich, D. L. Royer, D. E. Soltis, P. F. Stevens, M. Westoby, I. J. Wright, L. Aarssen, R. I. Bertin, A. Calaminus, R. Govaerts, F. Hemmings, M. R. Leishman, J. Oleksyn, P. S. Soltis, N. G. Swenson, L. Warman, and J. M. Beaulieu. 2014. Three keys to the radiation of angiosperms into freezing environments. *Nature*. 506(7486): 89-92

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O'Meara, B.C., C. Ané, M.J. Sanderson, and P.C. Wainwright. 2006. Testing for different rates of continuous trait evolution using likelihood. *Evolution* 60: 922-933.

Up to Five Other Products

Stoltzfus, A., H. Lapp, N. Matasci, H. Deus, B. Sidlauskas, C. Zmasek, G. Vaidya, E. Pontelli, K. Cranston, R. Vos, C. Webb, L. Harmon, M. Pirrung, **B. O'Meara**, M. Pennell, S. Mirarab, M. Rosenberg, J. Balhoff, H. Bik, T. Heath, P. Midford, J. Brown, E. McTavish, J. Sukumaran, M. Westneat, M. Alfaro, A. Steele, and G. Jordan. 2013. Phylotastic! Making tree-of-life knowledge accessible, reusable and convenient. *BMC Bioinformatics* 14:1-17

O'Meara, B., K. Graham, S. Pellis and G. Burghardt (2015). "Evolutionary models for the retention of adult-adult social play in primates: The roles of diet and other factors associated with resource acquisition". In: *Adaptive Behavior* 23.6, pp. 381-391.

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- Driskell, A. C., C. Ané, J. G. Burleigh, M. M. McMahon, **B. C. O'Meara**, and M. J. Sanderson. 2004. Phylogenetic utility of large sequence databases for building the tree of life. *Science* 306: 1172-1174

Synergistic Activities

1. Darwin Day Tennessee advisor
2. Curator of Phylogenetics task view for R
3. Organizer in Women in Science activities for Society of Systematic Biologists & at UT Knoxville
4. Organizer of multiple hackathons
5. Communications Director for the Society of Systematic Biologists