Progress Report of the Forest Health Research and Education Center

(March 31, 2017 to December 31, 2017)

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Summary

The Forest Health Research and Education Center (FHC) stabilized leadership this year under the co-direction of Dr. Dana Nelson, USDA Forest Service (USFS) Research Geneticist and Dr. Jeff Stringer, Chair, UK Department of Forestry and Natural Resources (FNR). Along with Dr. Nelson and Dr. Stringer, Dr. Thomas Ochuodho, Social Sciences Team leader, and Dr. Albert Abbott, Biological Sciences Team leader round out the FHC leadership team. The FHC benefits from additional core members Dr. Ellen Crocker, post-doctoral scholar on the Outreach and Education Team, led by Dr. Stringer, Dr. Tyler Dreaden, USFS Research Pathologist, and Dr. Shenghua Fan, Research Associate with the Biological Sciences Team. In addition, two post-doctoral scholars (Anna Conrad and Thais Barros Rodrigues), three graduate students (Kenton Sena, Rachel Landham and William Thomas) and 3 undergraduate students worked with the FHC on forest health centric projects during this period. The FHC has continued to successfully pursue a range of competitive grants to advance our research and educational objectives. During this period the FHC has attracted $268,481 in extramural funding with another $3,745,164 pending.

This report details some of the specific projects each team (i.e., Biological Sciences, Social Sciences, and Outreach and Education) has identified as priorities for their disciplines and areas of responsibility. The Biological Sciences Team has made exciting progress, in a wide range of projects, from genomic studies of several key trees and pathogens to work towards a gene-silencing option to control the emerald ash borer and southern pine beetle. The Social Sciences Team has initiated several new projects and collaborations including a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the white oak supply. The Education and Outreach Team developed a new citizen science mobile app (TreeSnap) for connecting the public to restoration breeding programs and continued work to with a diverse range of audiences to increase awareness of forest health threats, management options, and research progress. In addition, members from all teams have worked collaboratively on a range of projects including a Delphi expert opinion survey of white oak threats.

FHC leadership has initiated, in collaboration with, USFS NRS scientists a plan to advance genetic work on white oak and the Kentucky Distillers Association is providing funding in 2018 to advance this effort. Funding has also been secured to establish a forest genetics research position at the University of Kentucky to advance white oak genetics and tree improvement efforts in the region, with a total of $422,000 over the next 5 years anticipated to come from the Kentucky Spirits Research Institute, UK College of Agriculture Food and Environment, and the UK Department of Forestry and Natural Resources. This project will be aligned with the emerging White Oak Initiative. We look forward to the coming year when we plan to continue our grantsmanship to advance our research objectives, push forward on various projects, and continue to engage a broad network of forest health collaborators.

Funding

Funding received (5 grants totaling $268,481, bold names indicate FHC-affiliated):

- **Crocker E**, Arthur M, **Rieske-Kinney L**, **Nelson CD**, Lhotka J, and J Christian. Development of an Undergraduate Certificate in Urban and Community Forestry. USDA HEC. **$149,734.** Feb 2018.
- Agouridis C, **Crocker E**, Odom S, and R Hirsh. "Expanding Your Horizons- a STEM Workshop for Middle School Girls" NSF EPSCoR, **$5,600**. Nov 2017.
- Arthur M, Williamson N, Coy G, **Rieske-Kinney L**, Dameron, **Crocker E**, Borden S, Jennings C, and A Powell. Roots to Branches. UK Sustainability Challenge Grant Program. **$38,890.** Nov 2017.
- Agouridis C, **Crocker E**, Stamper D, Thomas L, Springer M, Sanderson W, Gumbert A, Barton C, Belton C, and W Long. Developing a KY Master Naturalist Program. UK Sustainability Challenge Grant Program. **$14,257**. Nov 2017.
- **Ochucodho T.** "Assessing Economic Values of Forest Ecosystem Services in Kentucky" Kentucky Agricultural Experiment Station. **$30,000 plus $30,000 match** from Department of Forestry and Natural Resources. Sept 2017.

Funding being sought or pending (5 grants totaling $3,745,164):

- **Crocker E**, Koch J, and **CD Nelson.** USDA AFRI Foundational Program Area, Pests and Beneficial Species in Agricultural Production Systems. Supporting The 2018 Conference "Tree Resistance To Insects And Diseases: Putting Promise Into Practice" **$50,000.**
- **Crocker E.** Citizen Science Tracking of Invasive Threats Through a Mobile App. KY Farm Bill, **$83,972.**
- Dvorak T, **Crocker E**, and R Hirsch. Sparking STEM: Integrating Biotechnology into Informal Youth Education to Train Tomorrow's Workforce. NSF Advancing Informal Science Learning. **$601,928**.
- Rignall K, **Ochuodho T**, Shade L, and J Yang. "Coupled Systems in Changing Energy Landscapes: Assessing How Land Ownership Mediates Natural and Human Processes in Central Appalachia" NSF Dynamics of Coupled Natural and Human Systems (CNH) Program, **$1,569,705.**
- Contreras M, **Ochuodho T,** Lhotka JM, Niman C. 2018. "Developing wood bioenergy opportunities in the central Appalachian region: understanding economic and spatial constraints on use of timber industry byproducts and low-quality standing timber for bioenergy" U.S. Forest Service Wood Innovations. $**267,386**.
- **Abbott AG, Dreaden TJ,** Merkle S, **Nelson CD, Staton M**. Genetic foundations of resistance to *P. cinnamoni* in Chinese chestnut NSF Plant Biotic Interactions, **$1,172,173**.

Unsuccessful proposals (5 grants totaling $10,343,663):

- **Nelson CD, Crocker E, Stringer J, and A Abbott**. University of Kentucky, Office of the Vice President. Forest Health Research and Education Center. **$480,000.**
- **Crocker E** and **T Dreaden**. Identification of endophytes of "lingering" ash for biological control of emerald ash borer. Tree Fund John Z. Duling Grant. $**17,058**.
- **Crocker E, Stringer J**, Barrett S, Benton E, Boby L, Heaton C, Hubbard B, Khanal P, Jackson B, and H Stelzer. USDA AFRI ELI REEU. Development of a National Forestry and Natural Resources Extension Fellowship. **$300,000.**
- **Crocker E**. USDA AFRI ELI Postdoctoral Fellowship. Integrated Forest Health Postdoctoral Fellowship. **$163,602.**
- **Crocker E**, **Thomas W, and J Stringer**. PAR+Extension: Comparing top-down versus bottom-up approaches to public engagement and education in natural resources. NSF Advancing Informal Science Learning. **$293,773**.
- **Conrad A.** Environmental impacts on dormancy regulation in fruit trees USDA-Abiotic Stress. **$489,230.**
- Carlson J, **Abbott A**, et al. Advanced genomic and genetic resources to bridge the phenome to genome in hardwood trees. NSF-PGRP. **$8,600,000**.

New personnel hires and collaborators

- New Social Sciences team collaborators were invited by Dr. Thomas Ochuodho: Craig Johnson (University of Wisconsin), Omkar Joshi (Oklahoma State University), and Neelam Poudyal (University of Tennessee) and have accepted
- Hired postdoctoral scholar Dr. Yang Bai as Geospatial/Economist Specialist (1 yr., starting September 2017) on the ecosystem services project.

Student research updates

- Undergraduate research interns working with Forest Health Center fall of 2017
  - Kelsey Phillips and Andrew Betts working on collaboration with Forest Stewardship Council white oak sampling
  - Hannah Moore working on forest health outreach
- Kenton Sena, PhD student in UK Department of Forestry, research project on *P. cinnamomi* distribution and mining land reforestation working with FHC. Sena received several awards for his FHC- related research during this period including:
  - Being selected as a participant in USDA Agricultural Outlook Forum Student Diversity Program, 2018.

- Storkan-Hanes-McCaslin Foundation Award, "Tracking a tree-killer: Modeling *Phytophthora cinnamomi* distribution in eastern Kentucky," **$8,000**, July 2017.
- University of Kentucky Appalachian Center Eller and Billings Student Research Award, "Tracking a tree-killer: Modeling *Phytophthora cinnamomi* distribution in eastern Kentucky (Project continuation)," **$1,000**, May 2017.
- 2nd Place Graduate Student Poster Presentation Award, Sustainability Forum, 6 December 2017, **$300**.
- 1st Place Presentation Award, Bill Witt IPSS Student Minisymposium, 1 December 2017, **$50**.

- William Thomas, PhD student in UK Department of Sociology, research project on woodland owner attitudes to woodland management.
- Rachel Landham, Masters student in UK Department of Forestry and Natural Resources, thesis research project on white oak genetics. Landham presented her work at the Southern Forest Tree improvement Conference in Melbourne, FL and earned 2nd place in the poster contest.

Biological Sciences Team Summary

The biological sciences team has made significant progress on key research projects in 2017.

1) We have finished a comprehensive mapping and genetic characterization of resistance to *P. cinnamomi* in chestnut and are currently utilizing this information for candidate gene mining and characterization.
2) Kenton Sena has completed his Ph.D. research on evaluation of *P. cinnamomi* presence in watersheds of Appalachia providing information critical to reforestation strategies for chestnut and other susceptible species.
3) We have advanced our objectives on understanding the control of dormancy and response to abiotic stress in trees as a critical step to addressing the challenges to sustaining our forest trees brought on by rapid climate change.
4) The Lynn Riske-Kinney laboratory has significantly advanced research on RNAi induced resistance to invasive beetle pathogens such as emerald ash borer.
5) We have completed studies on the genetics of *Raffaelea lauricola*, the laurel wilt pathogen and have begun to study the genetic structure of *Torreya taxifolia*, an endangered conifer to assist in development of species preservation strategies.
6) We have contributed significantly to the Chinese chestnut whole genome sequence assembly integrating our high-density molecular marker maps into the assembly process. This work will culminate this year with publication of the genome.
7) We have finished an exploratory project on the use of specific plant viruses as vectors to promote early flowering in forest trees with results suggesting that these viruses could serve this purpose. We are proposing to expand this work to a number of key forest tree species to provide an avenue for rapidly introgressing traits of importance to the breeding and conservation of these tree resources.

8) Finally, we have developed and proposed a white oak (*Q. alba*) genetics/genomics program as a first step in sustaining and improving this valued resource as part of the multiregional and institutional White Oak Initiative.

Detailed descriptions of the individual project accomplishments are provided below.

1) Phytophthora projects:

- Tatyana Zhebentyayeva, Clemson University, mapped resistance to *Phytophthora cinnamomi* in Chinese/American hybrid chestnut families. She finished the GBS maps of three families for Phytophthora resistance and one consistent QTL on LG E seems to be the case. Tatyana is finalizing and F2 map from a population started by Paul Sisco and these will all be used to develop a manuscript on Chinese chestnut resistance to PC. Tatyana is currently drafting then manuscript for submission later this year.

- Kenton Sena, University of Kentucky, assessed *Phytophthora cinnamomi* presence in water and soils from forests throughout Appalachia.

2) Abiotic stress projects:

- Anna Conrad, The Ohio State University, completed analysis of phenylpropanoid metabolites and gene expression in apricot buds as part of USDA AFRI NIFA abiotic stress project and prepared draft manuscript on results. She also completed analysis of phenylpropanoid metabolites in peach buds as part of UDSA AFRI NIFA abiotic stress project and gene expression analysis in peach is underway.
- Anna Conrad received additional funding from the American Chestnut Foundation to evaluate the use of chemical fingerprinting as a tool to screen hybrid chestnut for resistance to chestnut blight and Phytophthora root rot.
- Shenghua Fan, University of Kentucky, completed GWAS analysis using Nextgen sequenced 115 apricot germplasm lines with 15 years of flowering time phenotypic data. He discovered that various combinations of QTL (genes) were trigged to regulate flowering time by different winter temperature regimes. he is finalizing the list of candidate genes/networks and preparing the manuscript
- Meg Staton's Lab, University of Tennessee, made significant progress in analysis of new apricot transcriptome data. They received apricot transcriptome data from 4 cultivars across multiple dormancy timepoints and completed initial data processing that included read trimming, read mapping to the peach reference genome, gene expression quantification, and differential gene expression statistical analysis. The data is of excellent quality and reveals interesting patterns during dormancy, including the differential expression of pathways between endo- and eco-dormant stages: oxidoreductase activity,

hormone regulation, day length sensing, and, as previously confirmed, the dormancy-associated MADs box gene family (DAM genes).

- Meg Staton's Lab also received peach transcriptome data from a set of trees in Clemson, SC. Based on initial processing, it was determined that there was significant ribosomal RNA contamination with up to 90% of reads in some libraries. Collaborations are ongoing with Bert Abbot and the GeneWiz company representatives to determine the cause of this and identify possible solutions, including re-sequencing. Jiali Yu (PhD student) performed the analysis for both peach and apricot data.

3) Tree pathobiology studies:

- Tyler Dreaden completed the population genetic study of *Raffaelea lauricola*, the laurel wilt pathogen, which confirms the hypothesis of a single introduction to the US. The results will be used to screen for genetic resistance and to guide deployment strategies.
- Tyler Dreaden started developing a panel of microsatellite markers to identify *Torreya taxifolia,* an endangered conifer. The markers will be used to aid ex situ conservation, breeding strategies and elucidate the reproductive strategy of this rare species.

4) Apricot bulk sequenced genome-wide association study (GWAS) for plum poz potyvirus (PPV) resistance:

- Shenghua Fan performed a genome wide bulk segregant analysis using two Nextgen sequenced bulks, each composed of 12 F1 siblings derived from the cross of two apricot cultivars with high (cv. Harlayne) and low (cv. Marlen) PPV resistance. He identified 1779 candidate SNPs with larger than 50% allele frequency difference in two bulks and 121 candidate SNPs with larger than 70% allele frequency difference. We are further characterizing the potential functions in PPV resistance of these SNPs.

5) Rapid-cycle breeding project

- Shenghua Fan performed two inoculations of Agrobacterium GV3101 cells transformed with TRV-TFL1 and TRV-FT gene constructs on chestnut and white oak seedlings. He confirmed the presence of TRV virus in inoculated white oaks by detecting TRV specific cDNA bands from white oak leaf RNA samples.

6) RNAi for controlling beetle pests in our forests

- Lynn Riske-Kinney's lab, University of Kentucky, is evaluating the feasibility of using gene silencing as a means of suppressing emerald ash borer, *Agrilus planipennis* (EAB), an exotic, aggressive, tree-killing beetle that has caused the loss of millions of ash trees in urban and wildland forests. They have

shown that RNA interference (RNAi) can cause rapid and extensive beetle mortality and are now evaluating additional genes that, when silenced, could cause beetle mortality. They are also evaluating methods of delivery and assessing potential non-target effects.

- Stemming from the EAB RNAi project, Lynn Riske-Kinney's lab, is also investigating the potential for gene silencing in southern pine. The endemic southern pine beetle, *Dendroctonus frontalis*, is prone to population outbreaks that lead to landscape-scale tree mortality. They have determined that southern pine beetle has the cellular machinery necessary for RNAi, and are working on identifying suitable genes that will induce rapid beetle mortality. Once identified, they will evaluate methods of delivery and assess potential non-target effects.

7) Chestnut genomic projects:

- Meg Staton laboratory, University of Tennessee, has been involved with a range of bioinformatics projects related to chesnut genomics including:
    - *Chestnut pseudochromosomes and annotation:* In the past year they have worked closely with John Carlson (Penn State) and the FHC on improvements to the Chinese chestnut reference genome. They received a new assembly with 12,687 contigs in the fall of 2017. They have submitted them to NCBI and worked with their contamination screen results to yield a final set of 12,686 contigs. Repeat masking identified 50.75% of bases as part of repetitive elements, a reasonable amount in comparison to other angiosperm plant genomes. They are currently working on ordering and orienting the contigs into pseudochromosome order using five high-density genetic linkage maps for Vanuxem and backcross hybrids provided by collaborators (Bert Abbott, Dana Nelson and Shenghua Fan at the University of Kentucky and Tetyana Zhebentyayeva at Clemson University). Genomic scaffolds are being placed in chromosomal context by using sequences from genetic map markers and Basic Local Alignment Search Tool (BLAST). After that is complete, they will work to place more sequence contigs in their proper chromosomal location using structural homology information obtained by comparing chestnut to the peach reference genome and the high density oak genetic linkage map. They are also working toward a new set of high quality gene annotations for the chestnut genome. Matt Huff (Research Associate) and Jiali Yu (PhD student) both contributed to this work.
    - *Hardwood Genomics Project:* The Hardwood Genomics database (https://hardwoodgenomics.org) continues to provide public access to important forest tree genomic and genetic resources, including reference genome and gene sequences, transcriptomes, differential expression data, and SSR markers. Major improvements over the last

year include the addition of a powerful new search that allows users to use keyword search to find any type of data and a new BLAST tool that enables a user to BLAST their own sequence of interest to a reference genome and view the resulting hit in a JBrowse interface. Contributors to this work include Abdullah Almsaeed (Web Developer), Bradford Condon (Postdoc), and Ming Chen (PhD student).

- Shenghua Fan, University of Kentucky, refined the integrated Chinese chestnut genetic map constructed with two F1 crosses derived from three Chinese chestnut cultivars (Mahogany × Nanking and Vanuxem × Nanking) with additional SNP data genotyped with Infinium array. The new map is served as the backbone for Chinese chestnut genome assembly. He detected the reciprocal translocation between linkage groups H and L in Chinese chestnut Vanuxem and mapped blight disease resistance QTLs in chestnut breeding materials. We have integrated the genotypic and phenotypic data from 3 backcross and 1 F2 families and performed a GWAS analysis. Each backcross or F2 family is either too small or having ambiguous paternal parents for conventional mapping approach. The detected QTL in linkage group B using our approach is validated by other mapping projects.

Biological Sciences Team Research Publications *(bold names indicate FHC-affiliated)*:

- **Sena K, Crocker E**, Vincelli P, and C Barton. 2017. *Phytophthora cinnamomi* as a driver of forest change: Implications for conservation and management. *Forest Ecology and Management*. 409:799-807.
- Bell G, **Sena K**, Barton C, and M French. 2017. Establishing pine monocultures and mixed pine-hardwood stands on reclaimed surface mined land in eastern Kentucky: implications for forest resilience in a changing climate. *Forests* 8:375.
- Barton C, **Sena K**, Dolan T, Angel P, and C Zipper. 2018. Restoring forests on surface coal mines in Appalachia: A regional reforestation approach with global application. In, N.S. Bolan, M.B. Kirkham and Y.S. Ok, eds., *Spoil to Soil: Mine Site Rehabilitation and Revegetation,* pp. 123-146. CRC Press: Boca Raton, FL.
- Mullerin S, Black A, **Dreaden TJ** and JA Smith. *In review*. A host range study of *Diplodia corticola* and *D. quercivora*, pathogens on oak. Plant Disease.
- Stewart JF, Will RE, Crane BS, and **CD Nelson**. 2016. The genetics of shortleaf pine (*Pinus echinata* mill.) with implications for restoration and management. Tree Genetics & Genomes 12:98, DOI 10.1007/s11295-016-1052-5.
- Gailing O and **CD Nelson**. 2017. Genetic variation patterns of American chestnut populations at EST-SSRs. Botany 95:799-807.
- Santos C, **Nelson CD**, Machado H, Gomes-Laranjo J, and R Costa. 2017. First interspecific genetic linkage map for *Castanea sativa* x *Castanea crenata* revealed QTLs for resistance to *Phytophthora cinnamomi*. PlosONE (in press). (refereed)

- Potter KM, Campbell AR, Josserand SA, **Nelson CD**, and RM Jetton. 2017. Population isolation results in unexpectedly high differentiation in Carolina hemlock (*Tsuga caroliniana*), an imperiled Southern Appalachian endemic conifer**.** Tree Genetics & Genomes (in press).
- **Nelson CD** and JL Koch. 2017. Institute of Forest Tree Breeding: Improvement and gene conservation of iconic tree species in the 21st century. In: Proc. Workshop on Gene Conservation in Trees. May 16-19, 2016, Chicago, IL. (in press)
- **Rodrigues TB**, Duan JJ, Palli SR, and **LK Rieske**. 2018. Identification of highly effective target genes for RNAi-mediated control emerald ash borer, *A. planipennis*. *Scientific Reports, in press*.
- **Rodrigues TB**, **Rieske LK**, Duan JJ, Mogilicherla K, and SR Palli. 2017. Development of RNAi method for screening candidate genes to control emerald ash borer, *Agrilus planipennis*. *Scientific Reports*7:7379. DOI:10.1038/s41598-017-07605-x.

Biological Sciences Team Manuscripts in Preparation:

- **Sena S**, **Dreaden T, Crocker E**, and C Barton. Detection of *Phytophthora cinnamomi* in forest soils by PCR on DNA extracted from leaf disc baits. Major revisions requested, *Plant Health Progress*.
- **Sena K**, Yeager K, **Dreaden T**, and C Barton. *Phytophthora cinnamomi* colonized reclaimed surface mined sites in Eastern Kentucky: implications for restoration of susceptible species. Paper in preparation for submission to Forests special issue on "Forest Insects and Pathogens in a Changing Environment: Ecology, Monitoring & Genetics."
- **Fan S**, Georgi L, **Nelson CD, and A Abbott**. GWAS analysis detects blight resistant genes in chestnut using complex breeding materials.
- **Fan S,** Jaromczyk J, **Nelson CD, and A Abbott**. GWAS detects various QTL combinations regulating flowering time in different winter temperature regime.
- **Conrad AO,** Yu J, **Staton ME**, Audergon JM, Roch G, Decroocq V, Knagge K, Chen H, **Zhebentyayeva T**, Liu Z, Dardick C, **Nelson CD, and AG Abbott**. Association of the phenylpropanoid pathway with dormancy and adaptive trait variation in *Prunus armeniaca.*
- Smith KE, Hughes MA, Echt CS, Josserand SA, **Nelson CD**, Davis JM, and JA Smith. 2017. Using genetic information to inform redbay restoration in laurel wilt epidemic areas. In: Proc. Workshop on Gene Conservation in Trees. May 16-19, 2016, Chicago, IL. (in press)
- **Dreaden TJ,** Hughes MA, Ploetz RC, Black A, and JA Smith. Population Genetics of *Raffaelea lauricola*, the Laurel Wilt Pathogen. Journal of Forestry.

- Kobziar LN, Pingree MRA, Larson H, **Dreden TJ**, and S Green. Pyroaerobiology of wildland fire: how smoke and convection aerosolize and transport living organisms. Atmospheric Environment.

Biological Sciences Team Research Presentations:

- **Sena K**, **Crocker E, Dreaden T**, Clark C, and C Barton. 2017. "Tracking a Tree-killer: Detecting *Phytophthora cinnamomi* in Appalachian forests." Oral presentation at Soil Science Society of America Annual Meeting, Tampa, FL, October 22-25.
- **Sena K**, **Crocker E, Dreaden T**, Clark C, Yang J, and C Barton. 2017. "Tracking a Tree-killer: Improving detection and characterizing species distribution of *Phytophthora cinnamomi* in Appalachian forests. Poster presentation at Graduate Appalachian Research Community (GARC) Appalachian Research Symposium and Arts Showcase, Lexington, KY, February 19.
- **Sena K**, Bell G, Barton C, and M French. 2017. "Establishing Pine Monocultures and Mixed Pine-Hardwood Stands on Reclaimed Surface Mined Land in Eastern Kentucky: Implications for Forest Resilience in a Changing Climate." Poster presentation at Tracy Farmer Institute for Sustainability and the Environment (TFISE) Sustainability Forum, University of Kentucky, December 6.
- **Sena S**, **Crocker E, Dreaden T**, Clark C, and C Barton. 2017. "Tracking a Tree-killer: detecting *Phytophthora cinnamomi* in eastern Kentucky." Oral presentation at Bill Witt IPSS Symposium, University of Kentucky, December 1.
- **Sena K**, **Crocker E, Dreaden T**, Clark C, and C Barton. 2017. "Tracking a Tree-killer: detecting *Phytophthora cinnamomi* in eastern Kentucky." Oral presentation at EcoLunch, University of Kentucky, October 13.
- **Sena K, Crocker E, Dreaden T**, Clark C, Yang J, and C Barton. 2017. "Tracking a tree-killer: detecting *Phytophthora cinnamomi* in eastern Kentucky." Poster presentation at Lilley Cornett Woods Research Symposium. Skyline, KY, June 8.
- **Sena K**, **Crocker E, Dreaden T**, Clark C, and C Barton. 2017. "Tracking a Tree-killer: Detecting *Phytophthora cinnamomi* in Appalachian forests. Oral presentation at Sharing Work Across Appalachia, University of Kentucky Appalachian Center, Lexington, KY, November 15.
- **Sena K** and C Barton. 2017. "Green Forests Work in Appalachia: Restoring new and old surface-mined lands to native forests." Oral presentation to Asbury University Introduction to Research Class, February 28.
- **Conrad A**, Westbrook J, **Zhebentyayeva T**, Rodriguez-Saona L, Bonello P, James J, Jeffers S, Sisco P, Hebard F, Georgi L, **Staton M**, Audergon JM, Decroocq V, Liu Z, Dardick C, **Nelson CD, and A Abbot**. 2017. "Metabolomics approaches for tracking biotic and abiotic stress performance in tree improvement programs." Oral presentation at the 34th Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-22, 2017.

- **Conrad AO**, **Zhebentyayeva T, Staton M,** Audergon JM, Decroocq V, Liu Z, Dardick CD, **Nelson CD, and A Abbott**. 2017. "Variation in phenylpropanoid intermediates associated with adaptation to abiotic stress in the perennial tree species *Prunus persica* and *P. armeniaca*." Poster presentation at the American Phytopathological Society Annual Meeting, San Antonio, TX, August 5-9.
- **Rodrigues TB, LK Rieske**, SR Palli. 2017. "RNAi technology to manage emerald ash borer." Entomological Society of America National Meeting. Denver, CO, Nov. 5-8 .
- **Rieske LK**. 2017. "Mitigating impacts of the emerald ash borer, a highly aggressive forest pest, using new and old approaches." Invited seminar at West Virginia University Department of Plant and Soil Science, Morgantown, WV.
- Olson DG, **LK Rieske.** 2017. "Emerald ash borer host range expansion." Entomological Society of America National Meeting. Denver, CO, November 5-8.
- **Abbott AG**, **Zhebentyayeva T**, Sisco PH, Kubisiak TL, Olukolu B, Jeffers SN, James JB, Hebard FV, Georgi LL, **Staton ME, and CD Nelson**. 2017. "Genetic mapping of resistance to *Phytophthora cinnamomi* for American chestnut restoration in the southeastern United States." Plant and Animal Genome, January 2017, San Diego, CA.
- **Nelson CD** and **TJ Dreaden**. 2017. "SRS forest health research in KY." Daniel Boone Nation Forest roundtable with UK Forestry, Feb. 10.
- **Nelson CD** and **TJ Dreaden**. 2017. Contributed slides to USDA's presentation to IARPA's detecting genome editing workshop, Boston, MA, April 6.
- **Nelson CD** and JL Koch. 2017. "Institute of Forest Tree Breeding (IFTB)—A Proposal." Northern Forest Genetics Association Meeting, Rhinelander, WI, May 9-10.
- Condon B, **Crocker E,** Almsaeed A**, Conrad A, Abbott A**, **Nelson CD,** and **M Staton**. 2017. "Treesnap: a citizen science tool to help our forests." Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-21.
- **Landham R, Conrad AO**, Yang J, **Dreaden T**, Lhotka J, Contreras M, Burdine C, **Staton ME, Abbott AG,** and **CD Nelson**. 2017. "Effects of Thinning Regimes on Genetic Variation of White Oak (*Quercus alba* L.) in Eastern Hardwood Forests." Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-21 (poster, 2nd place award).
- Echt C, Josserand S, Crane B, Hipkins V, Burdine C, **Nelson CD**, and J Barnett. 2017. "DNA Markers to identify southern pines and their hybrids." Poster at Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-21.
- Smith K, Josserand, Echt, **Nelson CD**, J Smith. 2017. *"Persea* Species Restoration in Laurel Wilt Epidemic Areas". Oral presentation at the 34th Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-22.
- **Conrad A,** Westbrook J, **Zhebentyayeva T**, Rodriguez-Saona L, Bonello P, James J, Jeffers S, Sisco P, Hebard F, Georgi L, **Staton M**, Audergon JM, Decroocq V, Liu Z, Dardick C, **Nelson CD**, and **A Abbott.** 2017. "Metabolomic approaches for tracking

biotic and abiotic stress performance in tree improvement programs." Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-21.

- Islam-Faridi N, Casola C, Raska W, Majid MA, Byram T, Krutovsky K and **CD Nelson**. 2017. "Capturing Loblolly Pine Chromosomes for Genome Sequencing Using Laser Capture Microdissection Microscopy." Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-21.
- **Nelson CN**, Crane BS, Roberds JH. 2017. "U.S. Forest Service longleaf pine progeny test review and analysis." Southern Forest Tree Improvement Conference, Melbourne, FL, June 19-21.
- **Nelson CD.** 2017. "Hemlock wooly adelgid resistance in hemlock." SFIWC, Melbourne, FL, July 25-28.
- **Abbott AG, Nelson CD**, et al. 2017. TreeSnap for chestnut talk. NE-1333 meeting, Maggie Valley, NC, Sept. 9, 2017
- **Nelson CD**, Crocker EV, et al. 2017. TreeSnap for hemlock talk. FRA meeting, Waynesville, NC, Sept. 29, 2017
- Guldin J, **Nelson CD**, and BS Crane. 2017. "Shortleaf pine restoration." Fourth biennial Shortleaf Pine Conf., Galloway, NJ, Oct. 3, 2017
- **Nelson CD,** et al. 2017. Treesnap talk at TACF, S. Portland, ME, Oct. 6, 2017

Social Sciences Team Summary

The Social Sciences Team of the FHC's main goal is to foster understanding of the economic and cultural impacts of forest health challenges and forest management responses, at local, regional, national, and global levels.

Under new leadership of Dr. Thomas Ochuodho, the Social Sciences Team expanded its membership by recruiting new affiliates from other land grant institutions in the Southeast and Midwest (University of Tennessee, Oklahoma State, and University of Wisconsin). Detailed information about these new team affiliates are available on social sciences team webpage. These new additions to the team bring wide range of expertise in social sciences that will be great asset to the team as we make progress with new social sciences research agenda. The team has already identified some key research focus areas. However, lack of funding remains the main constraint for making progress. We look forward to brainstorm on potential funding sources for the team during the upcoming FHC annual meeting in April 2018.

The Social Sciences Team research agenda remained focused on the economic impact of forest health threats and continued on in the following specific projects:

- Delphi expert opinion survey of oak threats and their potential impacts - part 1 of economics impacts of sudden oak death.
- Identifying the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of White Oak Supply

- Impact of land use and climate change on water-related ecosystem services in Kentucky
- Factors affecting risk perception concerning prescribed fire in the United States

Note: Manuscripts arising from the four projects above are currently under preparation and some should be published before end of 2018.

Social Sciences Team Research Presentations *(bold names indicate FHC-affiliated)*:

- **Ochuodho T**, Lantz VA, and E Olale. 2017. "Economic Analysis of the United States-Canada 2006 Softwood Lumber Agreement." Conference presentation at the Society of American Foresters 2017 Annual Convention. Albuquerque, New Mexico. November 13-19.
- **Conrad A, Crocker E, Thomas W, Li X, Ochuodho T, Holmes T and CD Nelson**. 2017. "Delphi expert opinion survey to assess threats to oaks in the eastern United States." Poster presentation at Oak Symposium, Knoxville TN, Oct 24.
- **Thomas W,** Niman C, Springer M, Lhotka L, and **T Ochuodho**. 2017. "White Oak Supply Analysis: Identifying the Strengths, Weaknesses, Opportunities, and Threats in Regards to White Oak Supply." Presentation at the FHC Annual Retreat at Robinson Forest July 20.
- **Ochuodho T.** 2017. "Forest Ecosystem Services Assessment Project." Presentation at the FHC Annual Retreat at Robinson Forest July 20.
- **Ochuodho T**, Lantz VA, and E Olale. 2017. "Economic Analysis of the United States-Canada 2006 Softwood Lumber Agreement." Conference presentation at the International Society of Forest Resource Economics 2017 Annual Conference. New Orleans, Louisiana. May 30- June 1.

Outreach and Education Team Summary

The goals of the Outreach and Education Team are to increase awareness of forest health challenges, improve understanding of the new genetic technologies available for improving and restoring forest health, and promote the research work of the FHC. This team is lead by Dr. Jeff Stringer with postdoctoral scholar Dr. Ellen Crocker also taking an active role. The Outreach and Education team has continued to make great progress working with concerned citizens, forest owners, and forest industries to 1) understand and prioritize forest health concerns, 2) develop educational strategies to address these concerns and 3) engage with forest researchers to help define meaningful research avenues and utilize research results to develop solutions to forest health issues.

Current focuses of the Education and Outreach Team include:

- Increasing public and professional understanding of forest health

- Developing and promoting the TreeSnap citizen science app for forest tree research
- Enhancing forest health curriculum, student training, and engagement of underrepresented students
- Increasing understanding of biotechnology's potential in forest restoration
- Increasing awareness of the importance of urban forests
- Sharing and applying the research of the FHC

During this time period, ~630 people were reached by in-person or webcast educational programing related to invasive species, fungi, citizen science, and other forest health topics. In addition, this team has interfaced regularly with both the biological sciences team and the social sciences team and organized the first FHC annual retreat to share research progress and plans with 15 FHC members and collaborators on July 20, 2017. The Outreach and Education Team also initiated a quarterly e-newsletter providing updates on the progress of the FHC and continues to maintain the FHC website and Facebook page. The FHC Outreach and Education team also strives to engage with a more general audience of adults and youth regarding the importance of healthy trees and forests, including those in urban areas. Over 600 youth and university students were engaged through classes and programs and 3 university undergraduates were mentored.

This year, the Outreach and Education Team initiated a forest health-related citizen science project with the creation of the TreeSnap app, in collaboration with Meg Staton's team at the University of Tennessee (www.TreeSnap.org). This app connects members of the public to restoration tree breeding programs throughout the country including those working to identify trees surviving invasive insects and pathogens for use in breeding programs. This app, freely available for iPhone and Android, has attracted over 400 users and collected 604 tree observations from 21 states since its release in July 2017.

Outreach and Education Team Publications *(bold names indicate FHC-affiliated)*:

- **Crocker E**. 2017. The Good, The Bad, and the Unknown: A Close Look at Public Concerns About GE Trees. Kentucky Woodlands Magazine.

Outreach and Education Team Programs Organized:

- **Crocker E.** Organized UK Ag Biotech Day bringing high school students to campus to tour research labs and learn about biotechnology, July 22, 2017, University of Kentucky, 35 students, parents, and teachers.
- **Crocker E.** Organized UK Forest Health Research and Education Center Retreat and Research Symposium, July 20, 2017, Robinson Forest, 15 people
- **Conrad A and E Crocker.** Assisted in organizing the 3rd annual UK Society of Postdoctoral Scholars Annual Research Symposium and facilitated panel discussion on careers post PhD, June 2, 2017, 75 people
- **Crocker E.** Organized the KY Expanding Your Horizons STEM conference for

middle school girls, April 29, 2017, 120 middle school girls, 30 parents, 100 UK undergraduate and graduate students

Outreach and Education Team Courses Taught:

- **Crocker E.** Instructor, FOR 399, mentored 2 Forestry Seniors in a white oak sampling internship, Fall 2017
- **Crocker E.** Mentor, Natural Resources undergraduate student intern in practices of forestry Extension
- **Crocker E.** Guest lectured "Biotechnology and Forestry," FOR 400 Human Dimensions of Forestry and Natural Resources, Oct 18, 2017
- **Crocker E.** Guest lectured "Emerging Forest Epidemics," FOR 602, Global issues in Forestry, Sept 20, 2017
- **Crocker E.** Instructor, EXP 396 Engaging Girls in STEM: Leadership and Service Learning for the Expanding Your Horizons Conference, Spring 2017, Experiential Education, University of Kentucky
- **Crocker E.** Instructor, EXP 650 Engaging Girls in STEM: Leadership and Service Learning for the Expanding Your Horizons Conference, Spring 2017, Experiential Education, University of Kentucky

Outreach and Education Team Presentations:

- **Crocker E** and N Williamson. "There's an App for that: Forest Engagement Through Citizen Science" webinar, KY Forestry Extension Fall Webinar Series, Nov 28, 2017, 27 people
- **Crocker E** and H Moore. "Plant Detectives" workshop at GEMS (Girls in Engineering, Math, and Science) event, Lexington KY, Nov 11, 2017, 80 middle school girls
- **Crocker E**. Organized "Mulching 101" workshop with Stacy Borden as part of urban forest-focused workshop series, Nov 11, 2017, 5 people
- **Crocker E**. "Mushrooms and More From Your Woodland" webinar, KY Forestry Extension Fall Webinar Series, Nov 2, 2017, 102 people
- **Crocker E,** Condon B, Abdullah A, **Abbott A, Nelson CD,** and M Staton. TreeSnap: a citizen science tool to help our forests. Presentation, Floracliff Nature Preserve Open House, Lexington KY, Oct 28, 2017, 30 people
- **Crocker E,** Condon B, Abdullah A, **Abbott A, Nelson CD**, and M Staton. TreeSnap: a citizen science tool to help our forests. Seminar at UK Biology Department Ecolunch Seminar Series, Oct 27, 2017, 20 people
- **Crocker E,** Condon B, Abdullah A, **Abbott A, Nelson CD**, and M Staton. TreeSnap: a citizen science tool to help our forests. Poster presentation Oak Symposium, Knoxville TN, Oct 24, 2017, 100 people
- **Crocker E**. Judged invasive plant identification component of Win With Wood competition, Quicksand KY, Oct 3, 2017, 100 high school students
- **Crocker E**. "Mushrooms and More From Your Woodland" presentation, Central Kentucky Woodland Owners Short Course, Sept 23, 2017, 43 people

- **Crocker E**. "Kentucky Forest Health Update" Presentation to KY Highway Maintenance Workers meeting, Quicksand, KY, Sept 21, 2017, 60 people
- **Crocker E.** "Invasive Plant Species and the Emerald Ash Borer" presentation at Your Backyard Woods session on KY Wood Expo, Sept 16, 20 people
- **Crocker E.** "Citizen Science for your Woodland" presentation at Master Woodland Stewards Program, Sept 8, 2017, 20 people
- **Crocker E**. "Mushrooms and More From Your Woodland" presentation, Western Kentucky Woodland Owners Short Course, August 26, 2017, 36 people
- **Crocker E.** "Mushrooms and More From Your Woodland" presentation, Eastern Woodland Owners Short Course, August 12, 2017, 28
- **Crocker E,** Condon B, Abdullah A, **Abbott A, Nelson CD**, and M Staton. TreeSnap: a citizen science tool to help our forests. Oral presentation at meeting group of "Standards and CyberInfrastructure That Enable "Big-Data" Driven Discovery For Tree Crop Research," NSF PGRP grant, Storrs, Connecticut, July 31- August 1, 2017, 20 people
- **Crocker E,** Condon B, Abdullah A, **Abbott A, Nelson CD**, and M Staton. TreeSnap: a citizen science tool to help our forests. Poster presentations at EKU Biology Department Annual Retreat, Lilly Cornett Woods, June 8, 2017, 50 people
- **Crocker E** "An introduction to the Forest Health Research and Education Center" poster presentations at EKU Biology Department Annual Retreat, Lilly Cornett Woods, June 8, 2017, 50 people
- **Crocker E,** Condon B, Abdullah A, **Abbott A, Nelson CD**, and M Staton "TreeSnap: a citizen science tool to help our forests" digital poster at UK Society of Postdoctoral Scholars Research Symposium (awarded 2nd place in poster competition), June 2, 2017, 75 people
- **Crocker E** and **A Conrad**. "Tree Detectives" youth presentation as a part of the NerdSquad Park Takeover in Cardinal Valley Park, June 13, 2017, 35 elementary and middle school children.
- **Crocker E**. "Biotech, Forest Restoration and Conservation" interview with Talking Biotech Podcast, June 3, 2017, ~ 150 podcast listeners.
- **Crocker E**. Organized "Landscaping with native plants and managing invasives" with John Michler and Joyce Bender as part of urban forest-focused workshop series, April 22, 2017, 60 people
- **Crocker E**. "Urban Tree Health" UK Urban Forest Ambassador training, April 1 2017, 15 people