Relevant Literature Notes

**Introduction**

Pests and Pathogens

Two Paragraphs

1. The global implications of pests and pathogens

2. History of pests and pathogens in eastern deciduous forests

1. Chestnut blight (Anagnostakis 1987)

2. Dutch elm disease (Brasier 1991, 2000)

3. Hemlock Wooly Adelgid (Ellison et al. 2018)

4. Emerald Ash-borer (Herms and McCullough 2014)

Global Implications of Pests and Pathogens

* Nuisance forest insects and diseases pose a serious threat to eastern deciduous forests.
* Over 450 nonindigenous pests and pathogens have been introduced to the United States (Aukema et al. 2010), with 11 of the 18 species that cause significant levels of damage to host trees found in eastern deciduous forests (Lovett et al. 2016).
* Many of these diseases, which were introduced through woody material that was a result of international trade and globalization, have had devastating effects on forest composition/canopy structure (Fischer et al. 2013, potentially Aukema 2010).
* The American Chestnut (*Castanea dentata*), a dominant canopy species which composed 8-25% of temperate deciduous forests (Karban 1978; Conners 1988; Hanberry and Nowacki 2016) is confined to the understory as non-reproductive sprouts from old stumps or root systems (Elliot and Swank 2008, Anagnostakis 1987).
* The Emerald-Ash borer, which is considered to be the most destructive forest insect to invade North America (Aukema 2011), induces 100% mortality in all ash species found in eastern deciduous forests within a few years (Klooster et al. 2013), Herms and McCullough 2014, Abella and others 2019).
* Estimates of total loss for species with the earliest outbreaks (including Chestnuts and Elm) are very rough (Anderson Teixiera 2020) and could underrepresent total ABG lost to mortality **OR**
* We find that these species cause an additional (i.e. above background levels) tree mortality rate [biomass loss] of 5.53 TgC per year, with an additional 41.1% of the total live forest biomass in the conterminous United States is at risk of future loss (Fei et al. 2013), largerly driven by the mortality of these canopy species.

#Aukema et al. 2010 – Quantifies the number of pests and pathogens introduced to forests in the US (450 insects and 16 pathogens). Lovett et al. 2016 – States that 11 of the 15 species that are considered high impact are found in eastern deciduous forests.

#Fisher et al. 2013 – References the impact of intercontinental trade and globalization on the introduction of nonindigenous species and notes that many species originate in Asia. #Aukema 2010 – Requires further reading

# Karban 1978; Conners 1988; Hanberry and Nowacki 2016 – Provide estimates of chestnut abundance prior to the Chestnut blight, need to be double-checked. #Elliot and Swank – States that Chestnuts are confined to the understory #Anagnostakis 1987 – Describes the physiology of Chestnut trees post-blight. Might be considered common knowledge at this point?

#Aukema 2011 – Defines EAB as the nonindigenous forest insect with the greatest economic impact # Klooster et al. 2013 – EAB induced mortality within stands occurs in a few years #Herms and McCullough 2014, Abella et al. 2019 – EAB induces 100% mortality in the three *Fraxinus* species found in eastern deciduous forests, need to be double checked. Are there more than three ash species in eastern deciduous forests?

* General statements about pests and pathogens
  + What they are, how they spread
  + Globalization, quantify global impact (Look into Aukema et al. 2010, Boyd et al. 2013)
* The United States continues to accumulate nonnative forest insects at the rate of ~2.5 per year, with “high-impact” insects and pathogens accumulating at 0.43 per year (Aukema et al. [2010](https://esajournals.onlinelibrary.wiley.com/doi/10.1890/15-1176#eap1331-bib-0003)),
* “Forests in the United States have been invaded by more than 450 pests and pathogens (455 insects and 16 pathogens) ” (Aukema et al. 2010).
* “We find that these species cause an additional (i.e. above background levels) tree mortality rate [biomass loss] of 5.53 TgC per year” (Fei et al. 2013).
  + “Compensation, in the form of increased growth and recruitment of nonhost species, was not detectable when measured across entire invaded ranges but does occur several decades following pest invasions” (Fei et al. 2013) – Not sure about using this one
* “In addition, 41.1% of the total live forest biomass in the conterminous United States is at risk of future loss from these 15 pests” (Fei et al. 2013) – See if any one these 13 include our four pests/pathogens
* “Nonnative pests (insects and diseases) can have multifaceted short-term and long-term impacts on forest ecosystems, ranging from
  + decreased forest productivity (Lovett et al. 2006)
  + the modification of biogeochemical cycling (Lovett et al. 2006)
  + geomorphic processes (Fei et al. 2014)
* Which can be detrimental to ecosystem services” (Seidl et al. 2018, Boyd et al. 2013)

History of Pests and Pathogens in Eastern Deciduous Forests

* Pests and Pathogens pose a serious threat to Eastern Deciduous Forests specifically
* 11 of the 15 pests that cause “substantial damage” are found in the eastern United States, in addition to 3 more that have the potential to cause significant damage (Fei et al. 2014, Lovett et al. 2016)
* Pests and pathogens impacted 22 tree genera in the Appalachian/Blue Ridge Eco-Region (Anderson-Teixiera 2020).
* Chestnuts
  + Introduced from Eastern Asia (Lee et al. 2005, Myburg et al. 2004) and first detected in 1904 (Anagnostakis 1987)
  + Introduced through infected chestnut trees (Griffin 1986)
  + Chestnut trees were described as “previously abundant” in 1939 (Berg and Moore 1941 – weak source)
  + Accounted for 8-25% of dominant trees in the study region (Karban 1978; Conners 1988; Hanberry and Nowacki 2016 – check these sources)
  + Within 50 years, the canopy tree was confined to the understory, which has significant ecological and economic consequences (Elliot and Swank 2008).
  + Persists as non-reproductive sprouts from old stumps or root systems (Anagnostakis 1987).
* Elms
  + First detected in 1930 (May 1930). It originated in East Asia but spread to the US from Europe (Fischer et al. 2013)
  + Introduced through imported logs (Beattie 1933)
  + Elm Trees (*Ulmus americana and ulmus rubra*) were described as “sparse” before the arrival of Dutch Elm Disease (Berg and Moore 1941)
  + Hinders water transportation and kills the tree within weeks (Fischer et al. 2013)
  + Within 50 years, it killed 50-100 million trees (Updated stat?)
* Hemlock Trees
  + First detected in the 1950’s (Gouger 1971) and introduced from Japan (Havill et al. 2006)
  + Tsuga canadensis experience nearly 100% mortality upon exposure to the adelgid, and untreated trees will likely be extirpated from the entire mid-Atlantic region before 2050 (Ellison et al. 2018 – check this source)
* Ash Trees
  + Introduced from Asia and first detected in 2002 (Capparet et al. 2005)
  + Likely imported via crates, pallets or other materials made from Ash wood (Capparet et al. 2005).
  + EAB-induced mortality occurs within stands within a few years (Klooster et al. 2013)
  + Ecological effects include altered understory environment, nutrient cycles, successional trajectories, facilitation of the spread of light-limited species and increased coarse woody debris (Herms and McCullough 2014)
  + Prior to its decline, the AGB of Ash trees was increasing or stable (Anderson-Teixiera 2015).
  + The three Fraxinus species (all critically endangered) undergo nearly 100% mortality of reproductively mature individuals from emerald ash borer (Herms and McCullough 2014; Abella and others 2019 – check these sources).
    - Are all species in eastern deciduous forests affected?
  + Considered the most destructive and costly *forest insect* to invade North America (Aukema 2011).
* Pests and pathogens were associated with notably elevated mortality rates and steep declines in abundance and AGB (Anderson-Teixeira 2020).
* Estimates of total loss for species with the earliest outbreaks (including Chestnuts and Elm) are very rough (Anderson Teixiera 2020) and could underrepresent total ABG lost to mortality
* Effects nutrient cycling (Fischer et al. 2013)

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Pest and Pathogens Literature Notes

Harvey et al. 2023 (Emergent hotspots of biotic disturbances)

* Describes the concept of two or more biotic disturbance occurring at the same time; rest of the paper is on Western forests

Anderson-Teixiera et al. 202

* Discusses potential limitations with the mortality survey data that we could use in our paper (specifically, how it has the potential to mis-attribute mortality to pests and pathogens when it should be attributed to native pests and pathogens, environmental stress or typical successional patterns – ex. species that are impacted by less virulent pests and pathogens, like Elm trees and Dutch Elm Disease)

Recruitment Failure

Outline

* Nuisance species have a profound impact on regional ecosystems
* There is a documented overabundance of white-tailed deer (*Odocoileus virginianus*) (*Publication referenced in McGravey et al. 2013*) which can be attributed to human influence (*Publication referenced in McGravey et al 2013*)
* White-tailed deer consume seedlings and saplings, negatively impacting seedling and sapling survival, density and growth (*Publications referenced in McGravey et al. 2013*, *Holm et al. 2013*)
* This can lead to decreased understory diversity, decreased canopy diversity and species richness and decreased abundance of dominant species in a typical forest (in this case Quercus spp.) (*Holm et al. 2013*)
* Define or contextualize non-endemic plants (Look for a reference)
  + Working definition: Plants that were not historically present in an area, region or ecosystem or were found at different abundances or densities
* Deer selectively browse on palatable species, and some non-endemic species, including pawpaw, are considered non-palatable by deer (*McGravey et al. 2013*) This can create dense stands of non-endemic species (*Knauer et al. 2023*)
* Non-endemic species may be able to utilize niche space in a forest faster or more efficiently (Reference - considered common knowledge?)
* As a result, they may be able to out compete endemic species
* These nuisance species can contribute to recruitment failure
  + Consider defining and contextualizing recruitment failure a little more here
  + The effects of these recruitment failure on species composition and forest structure are often not apparent for decades (*McGravey et al. 2013* - potentially move to regeneration debt paragraph).

Recruitment Failure Literature Notes

McGarvey et al. 2013

* Chronic over-browsing by white tailed deer can influence the life history of forests
* Deer browsing had the greatest effect on seedling establishment
* Browsing has an effect with smaller stems and saplings, but less of an effect on larger stems
* The effects of deer browsing might not be apparent in species composition and forest canopy for decades
* An increase in white deer over the past 50 years, which can be attributed to human influence
* Deer browsing reduces seedling survival rates and densities
* Deer selectively browse on palatable species
* Some non-endemic species, including pawpaw, are considered to be unpalatable to deer
* Seedling height and small-sapling abundance were most effected

Knauer et al. 2023

* Heavy browsing by deer reduces palatable species, which can create ideal conditions for dense stands of unpalatable native, non-native and browse-resistant stands to form
* Removing deer for long periods of time (8-20 years) does not lead to increased species diversity (in the understory?); the understory remains depauperate (poorly or imperfectly developed)
  + Once browsing has reduced species to low levels of abundance, it can take decades for them to recover
* Browsing can lead to species being extirpated or be sparsely distributed locally or regionally
* Many forest understories, especially in urban-fringe forests, and infested with non-endemic plants

Holm et al. 2013

* In a model predicting the effects of deer browsing on forest composition in 200 years, deer browsing decreased understory diversity, decreased species richness and decreased the abundance of Quercus spp. (a dominant species in this forest type)
* Gap disturbances exacerbated these impacts (could tie into paragraph on non-endemic pests and pathogens and tree mortality)
* Deer browsing can reduce survival and growth of several woody species and change the dominance rank of species at the sapling stage
* Impacts of browsing are likely to be greater in areas with high gap disturbance
* Deer herbivory on saplings reduced tree diversity in the understor

*Read this source for pawpaw life history traits – potential reference*

Intensive Selective Deer Browsing Favors Success of *Asminia trloba* (Paw paw) a Native Tree Species

*Cut-out sentences*

White-tailed deer preferentially browse on woody herbaceous species in their earliest life stages (Reference), with overabundant herbivory negatively impacting seedling and sapling survival, growth and density (Reference). Long-term/chronic overabundance could contribute to decreased understory diversity and fewer individuals from traditionally dominant species (Reference)./ Models predict that chronic overabundance will reduce understory diversity and decrease the abundance of traditionally dominant species (Reference)./Models of mid-Atlantic mesic forests predict that chronic overabundance of white-tailed deer will reduce future understory diversity and decrease the abundance of traditionally dominant species (Reference).

Methods

Site Description

The study was conducted in the 25.6-hectare Large Forest Dynamics plot at the National Zoo and Conservation Biology Institute in Front Royal, Virginia (38° 53’36.6“N, 78° 08’43.4 “W). The plot, which is located in the central Appalachian Mountains adjacent to Shenandoah National Park, is composed of secondary eastern mixed deciduous forest. Situated in the Appalachian Oak forest region, the canopy is dominated by tulip poplar (*Liriodendron tulipifera*), oak (*Quercus spp*.), and hickory (*Carya spp.*) and the understory is primarily composed of spicebush (*Lindera benzoin*), paw-paw (*Asimina triloba*), American hornbeam (*Carpinus carolinianai*) and witch hazel (*Hamamelis virginiana*) (SCBI site description). The land-use history of the site is varied, including periods of agricultural development and intensive logging, with dendrological data estimating canopy tree establishment around 1900 (SI archives, Bourg et al. 2013). Natural disturbances at the plot consist of wind and infrequent ice storms (Anderson-Teixiera 2015). The plot, which includes a 4-hectare deer exclosure that has decreased the presence of deer since 1990, is divided into 640 quadrats, each measuring 20 x 20 meters. It is one of 78 sites in the Forest Global Earth Observatory (ForestGEO), a global network of forest dynamic plots that promotes comparative forest ecology studies around the World.

ForestGEO Census

A number of surveys are regularly conducted at the site, four of which are included in our analysis. As part of the ForestGEO network, the plot undergoes a comprehensive woody plant inventory every five years, according to the protocol outlined in Condit (1998). This inventory, hereby referred to as the census, includes all stems greater than 1 centimeter in diameter at 1.3 meters in height (referred to as diameter at breast height or dbh). The census records information regarding the dbh, species, status and location of each stem included in the survey. Each plant is assigned an identifying number for sequential data collection in subsequent censuses and outfitted with a metal tag in the field. For multi-stemmed individuals, each additional stem that surpasses the 1 cm dbh threshold receives a stem number and associated tag. The location of each individual within its respective 20 x 20 meter quadrat is recorded on a map of the plot on ArcGIS FieldMaps. Established in 2008, there have been 4 censuses at the site, comprising 20 years of detailed forest dynamics data.

\*Is dbh considered common knowledge? Does it need to be defined?\*

\*Check with Luca to use consistent terminology here and in the analysis portion of the methods for ID tag, stem tag, etc.\*

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Mortality Survey and Invasive Species Survey

In addition to the ForestGEO census, an annual mortality survey is conducted on the site. Through assessing individual tree health, this study illustrates trends in forest mortality and identifies factors that are associated with death. Data is collected on the current status, canopy position, percentage of crown living and intact, and visible indicators of poor tree health, such as physical damage, potential pathogens and insect infestation. Furthermore, an invasive plant survey is conducted in conjunction with [the mortality survey or the census]. This study evaluates the establishment of non-endemic plant species and patterns of spatial distribution. Quadrats are visually examined for non-endemic plant species, with an estimation of the area covered by each species represented on a 1-5 numeric scale.

Methods Notes

* Located in the Oak Chestnut forest region (SCBI Github)
* Located at the intersection of the Blue Ridge, Valley and Ridge and Piedmont physiographic provinces (SCBI Github)
* Annual mean temp of 12 C° (SCBI Github)
* Annual precipitation of 1001 mm (SCBI Github)
* Elevation ranging from 273 to 338 meters, with a topographic relief of 65 meters (SCBI Github)
* Composed of secondary eastern deciduous forest (SCBI Github)
* Biome class of Cfa (humid subtropical/mid-latitude with significant precipitation all year) (SCBI Github)
* Natural disturbances consist of wind and ice storms (Anderson-Teixeira 2015)
* 640 20 x 20 meter plots
* Land use includes agriculture and logging (SI Archives)
* Most canopy trees were established circa 1900 (Bourg et al. 2013)

References

SCBI site description (Github)

<https://scbi-forestgeo.github.io/SCBI-Plot-Book/physical-environment.html>

Bourg et al. 2013

<https://www.researchgate.net/publication/257296875_Initial_census_woody_seedling_seed_rain_and_stand_structure_data_for_the_SCBI_SIGEO_Large_Forest_Dynamics_Plot>

SI Archives

<https://siarchives.si.edu/history/smithsonian-conservation-biology-institute-scbi>

Anderson-Teixeira 2015

Anderson‐Teixeira, Kristina J., Stuart J. Davies, Amy C. Bennett, Erika B. Gonzalez‐Akre, Helene C. Muller‐Landau, S. Joseph Wright, Kamariah Abu Salim, et al. 2015. “CTFS-ForestGEO: A Worldwide Network Monitoring Forests in an Era of Global Change.” Global Change Biology 21 (2): 528–49. <https://doi.org/10.1111/gcb.12712>.