Forest Health Handbook, 3rd Edition

The North Carolina Forest Service Forest Health Handbook describes some of the most important and/or common forest insects and diseases that damage trees in North Carolina. The main purpose of this manual is to provide basic information on threats to forest health, guidance in diagnosing tree disorders, and pest management recommendations. It is not intended as a final reference when dealing with any of the pests described. Rather, it should serve as a training aid and introductory text for those unfamiliar with the forest entomology and pathology fields, and as a quick reference guide for specific insect and diseases problems. **The information provided is specific to North Carolina.**

The **3rd Edition of the Forest Health Handbook** provides much of the same information as its predecessors. Insects and diseases are divided into sections based on the type of damage caused. For each specific stress agent, a brief overview is provided followed by information on the causal agent, hosts, symptoms and signs, life cycle or disease cycle, importance, management recommendations, seasonal timelines, and distribution information. This edition also features color photographs to supplement descriptions of symptoms/signs, to assist with diagnoses in the field, and to illustrate concepts or examples. Introductory material on forest protection, forest health, pathology, and entomology are provided to introduce readers to the terms and concepts used in these forestry sub-disciplines. Finally, a set of appendices is provided at the end of the manual with additional information on tree physiology and anatomy, non-native invasive organisms, diagnosing tree disorders, sample collection and submission guidelines, plant disease/insect management, additional resources and references, and Forest Health Branch contact information.

Time-sensitive information was excluded from this handbook (when possible) to prolong its relevance and usefulness. Therefore, information on the distribution of non-native invasives, laws and regulations, and pesticide use information may be found lacking or over-generalized in this manual. Readers are encouraged to consult the list of additional resources at the end of the handbook for current, time-sensitive information on these topics.

An effort was made to utilize (to the greatest extent possible) images from ForestryImages.org, an online source for forest health, natural resources, and silviculture-related images. This was done so that the reader can access original, high-quality images from the manual online for the purposes of study or diagnosis. Commercial use of these images has not been authorized. Image citations are provided at the end of the handbook; images from Forestry Images are available at: http://www.forestryimages.org/.

Introduction to Forest Protection

Forest protection is the scientific branch of forestry concerned with the study and control of ***biotic*** (living) and ***abiotic*** (non-living) stress agents that affect the health and/or integrity of trees, forest communities, and wood products. Stress agents are destructive and their effects must be limited to protect and conserve our forest resources, maintain tree health, and provide forest products for current and future generations. Historically, forest protection has primarily been concerned with fire science and fire control. Biotic stress agents have been the focus of two major branches of forest protection: ***forest entomology*** (the study of insects) and ***forest pathology*** (the study of pathogens and disease). The study and control of other abiotic stress agents has traditionally been shared by forest protection and silviculture.

This book will focus primarily on the biotic forest stress agents (primarily insects and diseases), though brief consideration will be given to abiotic stress agents with the notable exception of fire. The reason for this exclusion is two-fold. First, the science of fire and fire control are sufficiently different from other aspects of forest protection; consideration of fire and fire control is provided elsewhere in far more detail than can be provided here. Second, while fire is a major concern because of its destructive potential and threat to human safety, its negative impact on forest health is relatively minor in comparison to the other stress agents. For instance, in one of the few studies of its kind, the U.S. Forest Service estimated that in 1952, losses in forest productivity (tree mortality and reduced tree growth) due to forest stress agents in the U.S. equaled approximately 90% of the sawtimber volume cut in the same year. Of this staggering loss, 45% was due to disease, 20% due to insects, 18% due to abiotic factors such as weather, and only 17% due to fire.

Forest protection is a scientific discipline that requires an understanding and utilization of the principles and practices of not only forest pathology and forest entomology, but also forest ecology, forest management, silviculture, tree physiology, tree anatomy, soil science, physics, chemistry, and general biology. Likewise, forest protection is a critical component of ***silviculture*** which is the science of forest establishment, growth, and composition. In addition, stress agents (particularly insects and microorganisms) play a critical role in determining the health and diversity of forest communities; therefore, an understanding of forest protection is necessary for proper forest management and the science of forest ecology. Forestry as we know it would not be possible without an understanding and appreciation for the principles and practices of forest protection and its inter-related disciplines. The ultimate goal of forest protection is to minimize tree mortality and growth loss due to forest stress agents, and thereby protect and preserve healthy forest communities. But what exactly is a healthy forest?

Forest Health

Forests are tree-dominated communities of plants, animals, and microorganisms that interact with each other and the forest's abiotic components including soil, water, landform, and climate. A simplified example of a forest community would be a typical food web which includes producers, consumers, and decomposers: each organism in the food web is eaten by or eats other organisms. The totality of these interactions forms a network (or web) with connections present between all members of the community. In reality, the interactions and connections in a forest community are vast and complex, although the basic idea holds true: each component of the forest has an effect on and is affected by the others. Trees affect which plants and animals reside in the forest, protect soil from erosion, reduce runoff, improve water quality, and clean and cool the air. Likewise, the forest's abiotic components and organisms determine what tree species are found in a forest. Humans, for better or worse, are also an important constituent of forest communities because of our influence and reliance upon them. We rely upon our forests for a wide variety of resources, we value them for a range of social and cultural reasons, and they are an essential component of a healthy planet. Many forests are managed or protected to meet the goals and objectives of those who utilize and rely upon them; or are altered in ways that are damaging to the forest community.

A ***healthy forest*** is a forest that possesses the ability to sustain the unique species, interactions, and processes that exist within it and that can meet the present and future needs of people for a variety of values, products, and services. There are many types of forests found in North Carolina, each with a unique set of species, interactions, and processes. The health of our forests must be maintained to ensure the survival of plant and animal species that make the forest their home and to protect those processes that sustain a healthy environment.

A healthy forest can have unhealthy trees, just as an unhealthy forest can have healthy trees. Forest health can be determined on a variety of scales ranging from an entire forest ecosystem to an individual shade tree. A single dead tree in a large forested tract can provide wildlife habitat, may be an essential component of natural stand thinning or succession, or may create a gap in the canopy for a diversity of other plant species. However, a single dead tree in an urban forest might mean the loss of a high-value and prized shade tree, could represent years of lost revenue from a fruit tree that has taken years to bring to maturity, or may pose a hazard to people or structures nearby. Alternatively, the loss of many trees in a forest may not significantly impact forest health if other individuals of the same or similar species are able to support the community. But complete eradication of a single tree species by an insect or disease could have catastrophic consequences for a forest ecosystem. Defoliating insects and cosmetic diseases that are of little concern in forested situations may be intolerable afflictions to shade trees or ornamentals in a home owner's front yard. Annual growth losses due to poor soil conditions or drought may be of little concern in a park or on a tree-lined street, but could mean the loss of profitability over the course of a thirty year rotation in a pine plantation. The determination of forest health must be made relative to the species, processes, or resources of interest, and the stress agents present in the forest community.

Stress Agents

Tree health is threatened by ***stress agents*** that cause a sustained disruption of the normal physiological processes or structural functioning of a tree. Physiological processes include photosynthesis, respiration, transpiration, translocation of photosynthetic products and nutrients, growth, reproduction, mychorrizal associations, compartmentalization, and defensive responses. Structural functioning of the tree is dependent on anatomical features such as the roots and root hairs, root crown, stem, branches, buds, flowers, seeds, leaves, bark, and the vascular system. If a disruption in physiology or structure is sustained over a long enough period of time, or if it is severe enough, a tree can be harmed or killed. ***Primary stress agents*** are capable of attacking and injuring or killing otherwise healthy trees. A ***secondary stress agent*** can only attack a tree that has been weakened by primary stress agents or predisposing factors. ***Predisposing factors***, such as drought, extreme temperatures, nutrient deficiency, and fire, are most often abiotic stress agents.

Physiological or structural damage to trees due to non-living entities or ***abiotic stress agents*** are not considered to be diseases (diseases are caused by pathogens), but are more commonly referred to as abiotic disorders or abiotic injuries. Examples of abiotic stress agents include nutrient imbalances, improper soil pH, soil compaction, grade changes, hardpan, drought, flood, saltwater intrusion, lightning, frost, heat scorch, hail, sun scald, storm damage, mechanical injuries, herbicide damage, and air pollutants. Abiotic disorders are generally not species specific, meaning that most tree species are susceptible to most abiotic stress agents. Some tree species are more tolerant of abiotic stress agents or may have slightly different environmental preferences, but in general, an abiotic stress agent will affect most or all tree species to some degree. This can be particularly destructive when the stress agent is severe and widespread; entire forest communities can be severely damaged by a hurricane, drought, or environmental pollutants for instance. However, most abiotic disorders are relatively localized and they cannot spread from tree to tree. Management of acute injuries (e.g. mechanical damage and fire) emphasizes prevention prior to being damaged and possible treatments after the damage has occurred. Chronic disorders (e.g. drought and nutrient deficiencies) are less likely to be preventable, but may be treatable.

Biotic stress agents are living organisms including plants, animals, and disease-causing microorganisms such as fungi, bacteria, viruses, and nematodes. Most biotic stress agents are known as ***pests*** because they interfere with the intended use of a forest, a tree, or wood products. Some pests only inflict mechanical damage (e.g. a deer rubbing its antlers on the stem and damaging the bark) while others damage forest productivity through competition (e.g. weeds). The most important biotic stress agents are either predators or parasites; both attack trees to feed on or within them to obtain nutrients. ***Predators*** (in this case known as herbivores) are free-living organisms that usually feed on more than one individual host to reach maturity. ***Parasites*** on the other hand, live on or within a tree (usually one individual tree is sufficient to reach maturity) to obtain nutrients, and in the process they cause injury (*see* insects) or disease (*see* pathogens).

Biotic stress agents, specifically insects and pathogens, are transmissible; meaning that they can spread from one host tree to another. Although this may at first seem obvious, it is an important distinction for several reasons. First, the transmissibility of pests means that the disease or injury caused by them can also spread. When managing biotic stress agents that can spread, one needs to take into consideration movement of the pests across the landscape and through time. Simply controlling the pest at the site where damage or disease is occurring may not be adequate. Secondly, insect and pathogen populations have the potential to grow exponentially over time as they spread. This can result in outbreaks (insects) or epidemics (pathogens) capable of severe and widespread impacts on forest health. Third, biotic stress agents can only be transmitted to suitable hosts. Therefore, when monitoring, diagnosing, and managing biotic stress agents, one needs to take into consideration only the suitable host species.

Tree Stress Agents
Biotic
Abiotic
Plants
Alternate Hosts
Competitors
Parasites
Microorganisms
Viroids
Phytoplasmas
Viruses
Myxomycetes
Bacteria
Nematodes
Oomycetes
Fungi
Animals
Mammals
Meristem Feeders
Defoliators
Borers
Phloem Feeders
Insects
Birds
Disorders
Genetic Disorders
Girdling Roots
Deep Planting
Sun Scald
Weak Wood
Included Bark
Rubbing Branches
Wetwood
Frost Cracks
Soil
Grade Change
Compaction
Saltwater Intrusion
Drought
Slope
pH
Nutrient Excess
Flooding
Nutrient Deficiency
Micronutrients
Texture
Macronutrients
Hard Pan
Allelopathic Compounds
Toxins
Pesticides
Radiation
Air Pollution
Heavy Metals
Natural Gas
Misc. Toxins
Injury
Root Damage
Storm Damage
Pruning
Fire
Mechanical Damage
Girdling
Weather
Snow
Hail
Heat
Frost
Ice
Rain
Lightning
Wind

Hosts

A tree attacked by an insect or pathogen is called a ***host***. Most parasites have only one or a few tree species that act as suitable hosts, but a few parasites have a wider host range. This is because pests and trees have co-evolved over millions of years together and are engaged in an eternal "arms race" for superiority. Trees have evolved very powerful defensive responses to ward off attacks by potential parasites. Some of these defense responses are quite obvious (e.g. toxic chemicals, thick bark, leaf shedding, resin production, etc.) while others occur at a microscopic, chemical, or genetic level. In response, parasites have had to develop an arsenal of weapons (e.g. modified mouthparts, specialized digestive systems, toxins, enzymes, and even chemicals that shut off host defense responses) to survive. Because there are hundreds of thousands of plant species, insects and pathogens have evolved over time to "battle" just one or a few tree species; they could not possibly overcome the wide variety of defense adaptations found in all plant species. This means that most parasites are very host specific (i.e. they are very picky eaters). Some insects or pathogens can only complete their life cycle on a single tree species, or even on a single tree cultivar. The fact that most parasites are so extremely host specific has given rise to the saying: "resistance is the rule, susceptibility is the exception."

In general, a tree species is said to be ***resistant*** if it is capable of preventing or overcoming an attack by a specific parasite, but is said to be ***susceptible*** if that parasite can successfully attack, obtain nutrients, and disease or injury results. A tree can be resistant to one parasite, but susceptible to another. Resistance can be complete, meaning that the tree is not a host and can completely prevent a parasite from causing injury or disease; or it can be incomplete, meaning that the tree is susceptible to attack, but the severity of disease or injury is less than what would be observed in a less resistant (or more susceptible) species.