EMERGING HARDWOOD PEST PROBLEMS AND IMPLICATIONS FOR THE CENTRAL HARDWOOD REGION

Bruce D. Moltzan[1]

ABSTRACT.—Over the last 100 years of human action there has been a correlated increase in the movement of insects and disease to the new world. Chestnut Blight, Dutch Elm Disease, Gypsy Moth, Butternut Canker, and White Pine Blister Rust are stern reminders of historically devastating exotic invasions. Sudden Oak Death, Asian Long-horned Beetle, Oak Wilt, Red Oak Borer, and Oak Decline should be considered credible threats to the Central Hardwood region. The potential danger posed by these pests will necessitate increased plant inspection and regulation to reduce the impact of their arrival, establishment, and spread. Advanced risk assessment and detection linked with sound forest practice to promote species diversity will reduce the impact of unwanted exotic introductions.

The introduction of exotic invasive species to North America has often resulted in large scale tree mortality and the replacement of once dominant tree species. As compared to pests introduced to agronomic crops, the damage on forest ecosystems is greater because these tend to have long lived impacts (Liebhold and others 1995). Over the last 100 years the movement of people and increased trade in emerging global markets has led to a growing number of introduced biological pests (Pimentel 1986).

Co-evolution maintained overtime for a specific global location acts to sustain a dynamic state of equilibrium between populations of indigenous trees and their native biological pests. In other words, native tree/pathogen systems rarely produce a resistance that overwhelms the pathogen or a virulence that reaches epidemic proportions within a given host population. Barriers created by continental drift, oceans, mountains, and climatic extremes, to a large extent, maintain unequal distribution of most tree problems worldwide. When human movement overcomes these natural barriers, the likelihood of a non-native pest or host being deliberately or accidentally introduced will increase.

Fortunately, even if an invasive species does arrive in a non-native area the actual rate of establishment is very low. This can be attributed to the lack of reproducing populations or the absence of essential climatic conditions such as adequate moisture, humidity, and temperature preventing the development of persistent populations. Since both insect and microbial kingdoms have prolific adaptive capability, it should be apparent that the invasive agent if established would have an advantage over tree populations that lack co-evolved resistance.

Chestnut Blight, Dutch Elm Disease, Gypsy Moth, Butternut Canker, and White Pine Blister Rust all serve as significant reminders of exotic/introduced pests that successfully established in North America leading to the demise of once dominant tree species. The purpose of this paper is to discuss emerging and ongoing hardwood pest problems and their potential impact as they relate to the Central Hardwood region of the United States.

SUDDEN OAK DEATH

A disease now known as Sudden Oak Death (SOD) was first reported in 1995 in the central coastal region of California. The name of this disease was given in response to the rapid death occurring on tens of thousands of tanoaks (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.), coast live oaks (*Quercus agrifoli* Nee), and California black oaks (*Quercus kelloggi*i Newb.) killed by a newly described fungus *Phytophthora ramorum* (Werres and others 2001). On these hosts, the fungus causes a

[1]Forest Pathologist (BDM), Missouri Department of Conservation, 1110 S. College Avenue, Columbia, MO 65201. BDM is corresponding author: to contact, call (573) 882-9909 ext. 3311 or e-mail at bruce.moltzan@mdc.mo.gov.

Citation for proceedings: Van Sambeek, J.W.; Dawson, J.O.; Ponder, F., Jr.; Loewenstein, E.F.; Fralish, J.S., eds. 2003. Proceedings, 13th Central Hardwood Forest conference; 2002 April 1-3; Urbana, IL. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 565 p. [Research paper from invited keynote oral presentation].

bleeding canker on the stem. This is the most consistent and diagnostic symptom of the disease on larger trees and often develops before any visible foliage symptoms are evident. The distinction from other Phytophthora's is that SOD infections occur above ground up to 20 m (Garbelotto and others 2001, Rizzo and others 2002).

As of January 2002, SOD was known to occur only in California and southwestern Oregon, however, many new reports suggest it may have a broader distribution even into the mountain interior region of California. The geographic origin of this agent is currently unknown, but is believed to have been introduced from Germany and the Netherlands where it has only been reported on *Rhododendron* L. and *Viburnum* L. spp. (Werres and others 2001).

In ongoing tests, the fungus was shown to cause the disease on seedlings of northern red oak (*Quercus rubra* L.) and pin oak (*Q. palustris* Muenchh.) sent from the Central Hardwood region (Dave Rizzo, personal communication). This fact, coupled with widespread trading of rhododendron ornamentals, makes the introduction to the Central Hardwood forest a significant threat. Early detection will be important for successful eradication. Oaks defoliated early in the growing season by insects or pathogens may appear dead but leaves usually reflush later in the season.

Canker rots, slime flux, leaf scorch, root diseases, late season frost, herbicide injury, borer attacks, and other aliments may cause symptoms similar to those caused by *P. ramorum*. The most apparent of these are Oak Wilt, Oak Decline, and Red Oak Borer damage. In response to the SOD reports in southwestern Oregon, an aggressive campaign is presently under way to contain it by instituting a 100 m barrier zone followed by cutting and burning everything within the zone. If SOD were established in the Central Hardwood region, it most likely will be equally as aggressive. Often these approaches are not met with widespread acceptance by private landowners, so it may be a advisable to endeavor to educate the public of the potential threat.

Recently, the Animal and Plant Health Inspection Service, USDA, and others have issued quarantines restricting the movement of plants and other materials that might spread the SOD pathogen. This includes interstate shipment of potentially infested plants, foliage, wood, bark, and soil. Nursery inspections in the Pacific Northwest on rhododendron and azalea's now have more stringent requirements both in the nursery and prior to shipment. While this may be a good step forward, the fact remains that most states, particularly in the Central Hardwood region, cannot restrict the interstate movement of potentially infested material and many face budgetary deficits to adequately monitor for early detection.

Efforts are ongoing to determine whether climatic, topographic, and susceptible hardwoods similarly exist in the Central Hardwood region and whether these areas could be mapped in a risk assessment program. Currently, no infections on rhododendron sampled by the USDA Forest Service in the Southern Region, or samples sent to the Missouri Department of Agriculture have tested positive for this disease.

ASIAN LONGHORNED BEETLE

The Asian Longhorned Beetle (ALB), *Anoplophora glabripennis* (Motschulsky) is an exotic/invasive insect that represents a serious threat to the forest ecosystems of the Central Hardwood region and the entire United States. ALB is a native pest of China and Korea and has most likely been introduced into the United States within wood shipping crates packed from China. The ALB was first discovered in 1996 in New York City (Haack and others 1997) resulting in the removal of over 5,300 trees with recent infections (2002) reported near Central Park (Dennis Haugen, personal communication).

The ALB was also detected in appreciable populations within the greater Chicago area in 1998. Over 1,500 trees have been removed from infested urban areas with only a few new trees detected in recent surveys from infested areas. The beetle has also been detected in various ports and warehouses in other parts of the country and it is likely that other states have small isolated infestations that to date have not been detected.

The primary damage to the tree is caused by the ALB larvae that girdle the main stem and branches (Cavey and others 1998). If repeated attacks occur, the tree crown suffers dieback, eventually resulting in tree death. Damage from infestations in New York and Illinois has resulted in removal costs to State and Federal governments in excess of $80 million since the discovery of the infestations in 1996. If the ALB were to expand beyond the current quarantined areas of New York and Illinois, it has the potential to damage trees nationwide, affecting such industries as lumber, maple syrup, nursery, commercial fruit, and tourism and accumulating over $650 billion in losses.

The ALB hosts are primarily maple species, but beetles have been recovered on horse chestnut, chinaberry, mulberry, poplar, cherry, pear, locust, willow, elm, birch, ash, and citrus (USDA 2001). The beetle is described as glossy jet black with a very smooth body and having up to 20 distinct white spots on its back. The ALB can range in size from 20 to 32 mm in length. The distinct bluish tinge on the tops of the beetles' feet is diagnostic. Adults are usually present May to October. The biggest problem with managing this pest is the lack of accurate detection by green industry workers. Often damage will occur high in the tree where many large exit holes may be overlooked.

Trade with China has increased exponentially over the past decade. In 2000, imported commodities from China to the United States exceeded $100 billion. As a result, the risk of this plant pest as well as the potential of other invasive insects, plant diseases, and weeds being introduced into the United States has increased as well. Presently, APHIS works with the Chinese authorities to take steps to prevent future infestations of the ALB and similar pests, including restrictions on softwood packing material from China and imposition of treatment requirements for these materials before they arrive in the United States.

To prevent further introductions, APHIS continues to analyze threats to our agriculture and develop rules for importing commodities based on the risks they present. These inspectors form the first line of defense against exotic plant and animal pests and diseases. All international passenger baggage, cargo, packages, mail, and conveyances are subject to inspection upon entry into the United States.

It remains to be seen whether native hardwood populations in the Central Hardwood region would be at risk. Because the majority of the beetle's life is spent deep within the heartwood of host trees, it is difficult to control using contact insecticides. Although costly and undesirable, the only assured method of eliminating the beetle is to cut and chip or burn infested trees and replace them with non-host species.

OAK WILT

Oak wilt is a vascular wilt disease that severely impacts oaks caused by an aggressive fungus *Ceratocystis fagacearum*. Some plant pathologists believe oak wilt to be exotic in origin arriving in North America in the early 1900s, however the fungus has never been reported from any country other than the United States making its status as an invasive unlikely. Presently, oak wilt is found throughout the Central Hardwood region and eastern United States. Although the disease is not found west of Texas, controlled studies have shown that most oaks in the red oak group and many western species are at risk should the fungus become established outside its normal range (Appel 1994).

Oak species killed by oak wilt include black oak (*Quercus velutina* Lam.), northern pin oak (*Q. ellipsoidalis* E.J. Hill), northern red oak, shingle oak (*Q. imbricaria* Michx.), and Texas live oak (*Q. virginiana* Mill.). The disease is less common on bur oak (*Q. macrocarpa* Michx.), white oak (*Q. alba* L.), and other oaks in the white oak group presumably due to the physiology and morphology of their sapwood.

The oak wilt fungus moves from tree to tree via two different pathways: underground root graft connections or overland spread by insect vectors. Initial and long-distance spread of the oak wilt fungus occurs when beetles carrying spores of the fungus come in contact with wound openings causing infection and death of the tree. The time period necessary for mortality to occur ranges from a couple of weeks after introduction in red oaks to several years in white oaks (O'Brien and others 2000).

Once established, interconnected roots or root grafts provide the means for the fungus to transmit infection from diseased to healthy trees. In the southern portion of the Central Hardwood region, it is likely that insect vectors play a more prominent role in transmission than root grafts. This is because there are many species of oak intermixed in the forest, and clay based soils may prevent widespread root grafting (Johann Bruhn, personal communication).

Symptoms include rapid leaf discoloration and wilting of the entire crown of the tree. Subtle off green color may be visible in the upper crown and is usually apparent throughout the summer. Bronzing from the distal portion of leaves is often delineated by a discrete margin between diseased and healthy leaf tissue. Leaves are cast rapidly as the infection progresses. If the bark is stripped, it is possible to see brown streaking which is somewhat diagnostic.

Before costly controls are implemented, it is important to get accurate diagnosis from a qualified laboratory. Especially given there are many oak disorders that sometimes can be confused with oak wilt such as anthracnose, decline, and borer damage. Integrated management of oak wilt is built upon a variety of strategies to prevent new infection centers and limit the expansion of existing infection centers.

Once a center or pocket has been detected, removal of the dead trees will prevent a build up of inoculum in that area. Avoiding injury will also insure no openings for beetles to transmit the fungus. Recent studies suggest that as little as 15 minutes is all that is needed for fungal feeding nitidulids to find a wound. Proper timing of pruning should be restricted during peak periods of beetle activity and it should be noted that this may vary from north to south within the Central Hardwood region (Jennifer Juzwik, personal communication).

In the Lake States, the use of vibratory plows may sever root-grafts in sandy loamy soils. The blade should penetrate deep enough to disrupt grafted roots preferably to a depth of 5 feet. In the southern portion of the Central Hardwood region however, clay based, rock soils may make plowing difficult, at least a 3 foot depth is required to have an impact. In high value trees, it may be appropriate to inject trees with a propocanizole, however this seems to have a much better success rate in the white oak group and once administered must be repeated every 3 years.

More information is needed on how oak wilt differs in the north as compared to the south. In addition, update of the present distribution of oak wilt is of economic interest to those in the Central Hardwood region who seek markets in Europe where strict embargo of oak material exist. As the Central Hardwood forests become more fragmented, oak will continue to pose a high risk to urban and rural landowners.

OAK DECLINE/RED OAK BORER

Oak decline has worsened in the Ozarks recently due to a few years of drought and the advanced age of many oaks. While the complex is native to the Central Hardwood region, the result of this phenomenon is an ever-growing number of dead and dying oaks. Oak decline is caused by many environmental factors that together place stress on oak trees. Some of these factors have been present in southern Missouri forest stands for several decades.

The majority of trees affected by oak decline are in the red oak group. Within this group, the black oak and scarlet oak (*Quercus coccinea* Muenchh.) are the most severely affected. Many of these trees are over 70 to 80 years old and are growing in shallow, rocky soil on broad ridges or south and west-facing slopes (Starkey and others 1989). Often the stands are crowded with large numbers of mature trees. Trees growing under these conditions are competing heavily for limited water and nutrients. Over several years, a stressed tree becomes less vigorous, producing dwarfed, sparse foliage, and a thin crown. Branches in the upper crown begin to die back from the tips as tree growth is reduced. Various diseases and insects attack these weakened trees, stressing them even further.

In 1999, the USDA Forest Service estimated severe red oak decline and mortality existed on approximately 19,000 acres of the Ozark National Forest in northwest Arkansas. By June 2001, the estimated area of severe damage was approximately 300,000 acres. The numbers of red oak borer attacks had increased to unprecedented levels of 300 to 500 attacks per tree, compared to a more typical rate of less than 10 attacks per tree. The level of oak decline and mortality in Missouri was not as severe in 2001 as that observed in Arkansas, but there was increasing evidence of deteriorating conditions.

USDA Forest Service surveys in 2000 had estimated more than 16,000 acres on the Salem and Potosi Ranger Districts of the Mark Twain National Forest have high red oak mortality. *Armillaria* and red oak borers were clearly associated with dead and declining trees (Ross Melick, personal communication). By December 2001, the USDA Forest Service estimated that more than 100,000 acres on those two districts were seriously affected by decline and woodborer damage. Large acreages on other Ranger Districts were also seriously affected. Increasing levels of woodborer damage were observed in southern Missouri in 2001 on some private and state-owned land and on logs arriving at sawmills.

Tree crown dieback, reduced growth, and mortality caused by oak decline can have positive or negative impacts on the forest, depending on one's point of view. Cavities in dying trees can provide shelter or nesting sites for various species of birds and other animals. Openings that are created in the forest canopy may allow changes to occur in the composition of tree species present. Forest stands that were predominantly oak may change to mixed pine-oak type, or even pine type, which may be desirable, given that pine once dominated many of these sites.

On the other hand, there may be serious negative impacts to wildlife due to reduced mast (acorn) production, reduced oak regeneration capacity, and fewer preferred species in the developing forest. In a recent study, mast yield was reduced by greater than 41 percent when compared with potential mast yield in stands without decline. An increased number of dead and dying trees adds to fuel loading in the forest and may lead to increased risk of wildfire. The economic impacts of the recent woodborer damage in Arkansas may force some smaller sawmills to close within the next few years.

Prior to 1880, the pine and pine-oak forests in Missouri covered about 6.6 million acres. Shortleaf pine (*Pinus echinata* Mill.) was often in pure stands or otherwise shared the landscape with black, white, scarlet, and post oaks. The rugged terrain discouraged railroads from laying track in the region. However, as demand for lumber continued to increase, and the forests of the eastern and Great Lakes States declined in lumber production, lumber companies and railroads turned their attention in the 1880s to southern Missouri and northern Arkansas.

By the 1920s, most of the large trees had been cut, and the lumber boom ended. Both the people and the land were heavily affected by changes at that time. Young oaks in the understory of the former pine forests grew rapidly and were an obstacle to grazing. Some farmers used intensive grazing by goats and sheep to cut the oak sprouts, but most burned the woods to keep the hardwood thickets down and encourage grass growth. Such burns exposed the thin Ozark soils to erosion that removed nutrients needed for plant growth. Pine regeneration was limited under these conditions. Logging had removed most of the mature pines that could provide seeds. Frequent burning killed pine seedlings, but encouraged hardwoods to re-sprout thereby facilitating the forest we now see today.

Although many diseases and insects are involved with oak decline, the most common disease agents are *Armillaria* and *Hypoxylon* fungi, and the most common insects include the red oak borer and two-lined chestnut borer. All of these organisms are native to Missouri. *Armillaria* is a fungus causing white rot of woody roots and is found wherever trees are growing. *Armillaria* typically acts as a decomposer, decaying coarse woody debris that has fallen to the forest floor.

When trees become stressed or wounded, *Armillaria* can act as an aggressive parasite attacking the tree's root system. Infected roots no longer effectively take up water, particularly in drought-stressed soils, resulting in a reduction of live tree crown. If drought conditions persist or worsen, *Hypoxylon* cankers begin to form on the main stems of trees. Ordinarily, tree bark defends against attack from external fungal invaders like *Hypoxylon*. However, when trees are stressed, they cannot effectively maintain their defense and infection occurs. Once the canker has girdled the stem, portions of the tree above the canker will die.

The red oak borer is a reddish brown beetle that is 20 to 32 mm long and has antennae as long as or longer than the rest of its body. It has a 2-year life cycle, and most adults of this beetle emerge from their host trees in June and July of odd-numbered years. Large numbers of these adult beetles are expected to emerge in 2003. After mating, the adult female deposits her eggs in crevices in the bark of host trees, usually red oaks. The eggs hatch and young larvae chew their way through the bark and into the tree, where they will spend the next 2 years.

Red oak borer larvae, which look like white wormlike grubs, create a wide cavity in the phloem layer just under the bark during the first summer and the following spring. By the middle of the second summer, larvae begin burrowing into the sapwood and often go deeper into the heartwood of the tree. Each larva creates a $^{3}/_{8}$-inch diameter tunnel that extends for several inches by first angling upward away from the bark and then turning straight up through the wood. The adult red oak borer emerges from the tree in the third summer by chewing open a $^{1}/_{2}$-inch diameter oval hole in the bark near where it entered the tree as a young larva.

Periods of reduced growth of oaks, due to drought in most cases, have occurred in the Ozarks in 1901, 1909-1911, 1923-1924, 1935-1937, 1953-1954, 1972, and early 1980s, an average of about once every 14 years. Mortality due to oak decline was common in southern

Missouri following droughts of the 1980s, although not at the scale of current conditions. Oak decline management will need to seek to increase diversity of tree species and take into account only those species that are appropriate for the conditions of the site where they will be growing. Most poorly-formed trees and trees with unhealthy crowns should be removed, but it is beneficial to keep some standing dead trees and trees with cavities or wildlife habitat. For example, cavity-nesting birds such as woodpeckers are important predators of wood-boring insects.

Landowners may avoid oak decline effects by regenerating oak stands (harvest mature trees and allow seedlings and sprouts to re-stock the site) before trees become less vigorous due to old age. White oaks and post oaks are slower-growing and longer-lived than black and scarlet oaks. Under very good growing conditions, white oaks may live up to 600 years, while black oaks may live up to 150 or 200 years. Their life spans under most Missouri conditions, however, are typically much shorter.

Some people have argued that, because oak decline is a "natural" phenomenon, we should let nature take its course. But current forest conditions are partly the result of past management practices that created "unnatural" forests that are not healthy enough to withstand disease and insect attacks. Active management plans that restore and maintain the appropriate species on appropriate sites will improve forest health and reduce the need for drastic management intervention in the future

GYPSY MOTH

Further on the horizon looms the gypsy moth (*Lymantria dispar* L.), an introduced insect that has caused extensive oak defoliation and mortality for many decades across the northeastern United States. The gypsy moth continues to expand its range and could arrive in Missouri sometime in the next 15 to 25 years. Like oak decline, the gypsy moth's primary targets are the oak species. Trees that are already stressed by drought and oak decline will be less able to withstand repeated defoliation by gypsy moth caterpillars. Managing forests in the presence of gypsy moths requires reducing the number of trees of susceptible species and thinning out the least vigorous trees. The actions we take now will not only affect how our forests respond to oak decline, but will affect how well these forests survive the gypsy moth when it reaches Missouri.

SUMMARY

There is a need for all plant regulating agencies throughout the world to continually assess the potential risk to exotic pests, many of which are yet to be determined. Quarantines and the agencies responsible for maintaining them will need to be continually re-evaluated with increased movement of plant material. More research on forest pests in their country of origin may provide additional insight on the biology and management of these threats. A pro-active approach now that seeks to anticipate new arrivals will favor early detection giving foresters a greater window of opportunity to eradicate and prevent further spread.

Further, planting exotic tree species may prove to be an undesirable practice because exotic plants are highly susceptible to exotic pests (Pimentel 1986). Past experience with exotic invasions should move our thinking toward reducing our dependence on imported raw or processed wood products (Liebhold and others 1995). Forestry practice should minimize the use of one or only a few tree species and increase diversity in the Central Hardwood region to meet the demand for fiber in the future.

LITERATURE CITED

Appel, D.N. 1994. The potential for a California oak wilt epidemic. Journal of Arboriculture. 20(2): 79-86.

Cavey, J.F.; Hoebeke, E.R.; Passoa, S.; Lingafelter, S.W. 1998. A new exotic threat to North American hardwood forests: an asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae). I. Larval description and diagnosis. Proceedings, Entomological Society of Washington. 100(2): 373-381.

Garbelotto, M.; Svihra, P.; Rizzo, D.M. 2001. Sudden oak death syndrome fells three oak species. California Agriculture. 55(1): 9-19.

Haack, R.A.; Law, K.R.; Mastro, V.C.; Ossenbruggen, H.S.; Raimo, B.J. 1997. New York's battle with the Asian long-horned beetle. Journal of Forestry. 95(12): 11-15.

Liebhold, A.M.; MacDonald, W.L.; Bergdahl, D.; Mastro, V.C. 1995. Invasion by exotic forest pests: a threat to forest ecosystems. Forest Science Monographs. 30: 1-49.

O'Brien, J.G.; Mielke, M.E.; Starkey, D.; Juzwik, J. 2000. How to identify, prevent, and control oak wilt. NA-PR-03-00. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 28 p.

Pimental, D. 1986. Biological invasions of plands and animals in agriculture and forestry. In: Mooney, H.A.; Drake, J.A., eds. Ecology of biological invasions of North America and Hawaii. Ecol. Stud. 58. New York, NY: Springer-Verlag: 149-162.

Rizzo, D.M.; Garbelotto, M.; Davidson, J.M.; Slaughter, G.W. 2001. *Phytophthora ramorum* as the cause of extensive mortality of *Quercus* spp. and *Lithocarpus densiflorus* in California. Plant Disease. 86: 205-214.

Starkey, D.A.; Oak, S.W.; Ryan, G.W.; Tainter, F.H.; Redmond, C.; Brown, H.D. 1989. Evaluation of oak decline areas in the south. R8-PR 17. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 35 p.

United States Department of Agriculture. 2001. Asian long horned beetle [on-line]. http//www/na.fs.fed.us/spfo/alb/data/ilinfest.htm Posted September 2001.

Werres, S.; Marwitz, R.; Man In't Veld, W.A.; DeCock, A.W.A.M.; Bonants, P.J.M.; DeWeerdt, M.; Themann, K.; Ilieva, E.; Baayen, R.P. 2001. *Phytophthora ramorum* sp. nov., a new pathogen on *Rhododendron* and *Viburnum*. Mycological Research. 105: 1155-1165.