*In July 2002, the emerald ash borer (*Agrilus planipennis Fairmaire*) was conclusively identified as the agent responsible for the widespread decline of ash trees in southeastern Michigan and adjoining Ontario. As of February 1, 2013, the pest has caused the loss of some twenty million ash trees across eighteen states and two Canadian provinces. These losses might have been minimized if not for a series of errors, indifference, and slow responses by arborists and landscapers.*

FOOL ME TWICE, SHAME ON ME

THE EMERALD ASH BORER IN SOUTHEASTERN MICHIGAN

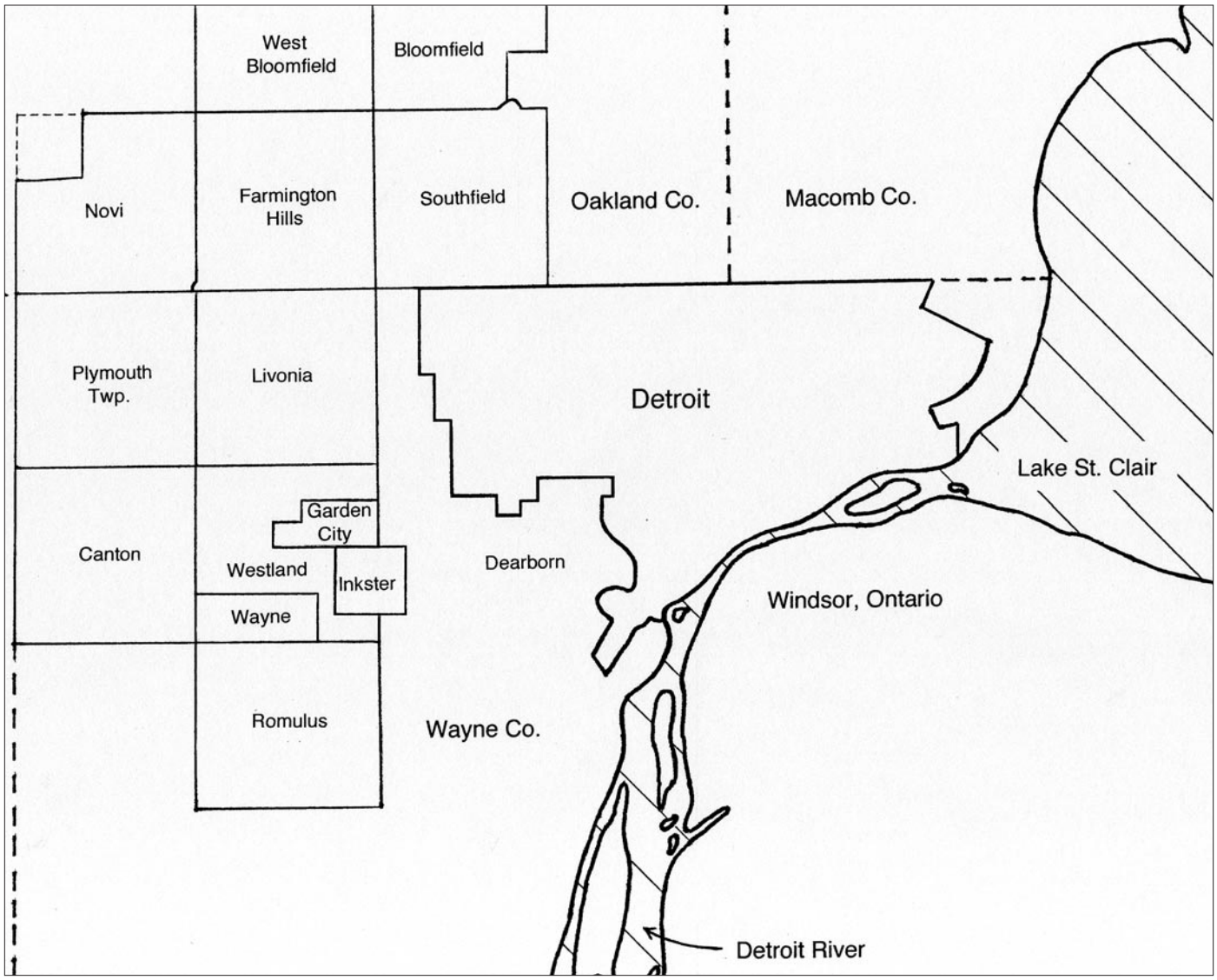
In 2001, landscapers and arborists in the Detroit metropolitan region first began to notice both the extent and the magnitude of the symptoms affecting the area's native ash trees. In what would come to be called the epicenter or core area of the infestation, something peculiar and profoundly wrong was happening to the ashes. But the slow response by landscapers and arborists, combined with indifference from residents in the affected areas and the decision made decades before to plant large numbers of ash trees in this urban setting, would exacerbate the problem. Before the culprit was identified a year later, the issue would become international in scope.

Understanding the basic geography of the area is necessary to understanding the story. In northwestern Wayne County, Michigan, which includes the cities of Detroit and Dearborn, there are a group of adjoining six-mile-by-six-mile townships, located almost immediately due west of Detroit, that had grown together as their suburban populations overflowed their political boundaries. They include Plymouth Township, Livonia, Canton, and Westland, and also the cities of Garden City, Inkster, and Wayne. The latter were also situated directly north of Detroit Metropolitan Airport, in the town of Romulus. Roughly speaking, the region is bordered on the north side by Interstate 96 and its extension to the west, Route 14; on the south side by Interstate 94; and transected north–south through the middle by Interstate 275 (temporarily joined by Interstate 96). With its high density, multi-ethnic population, and having to share Wayne County resources with Detroit itself, the area was largely characterized by a lower-income, blue-collar workforce.

To the north of this area lies Oakland County (whose east-to-west lower boundary is defined by 8 Mile Road, a major thoroughfare), and which also followed a division of lands into townships. Here, the cities of Novi and Farmington Hills are located, and beyond them, West Bloomfield and Bloomfield, where a spate of natural lakes are found. These areas are home to a generally more affluent white-collar workforce.

This area of Michigan suffered considerable droughts in 1998, 1999, and again in 2001, conditions that left many trees species moderately stressed and weakened and thus susceptible to attack by diseases and pests.[1] But the ash trees in particular began to

BY JORDAN D. MARCHÉ II



ORIGINAL MAP BY THE AUTHOR

Selected townships and cities in the Detroit metropolitan area (Wayne, Oakland Counties), where symptoms of ash decline were first recognized.

exhibit new and mysterious symptoms of profound distress in numbers never before witnessed. Initially, three species of ash, a member of the olive family (Oleaceae), were found to be threatened or affected: green ash (*Fraxinus pennsylvanica*), white ash (*F. americana*), and black ash (*F. nigra*). Two other, less common species, blue ash (*F. quadrangulata*) and pumpkin ash (*F. profunda*), were later added to the list.

Two primary symptoms were noted, the first being a significant thinning of the tree's foliage, sometimes accompanied by yellowing, which was especially obvious in the tree's upper canopy. This widespread effect became known as crown or canopy dieback. As the area's other trees had leafed out that spring, it had been noted that many ashes were either very slow to leaf out or did not leaf out at all. Many ash trees exhibited dead or dying branches, and a smaller number were entirely dead. Those affected with crown dieback generally died within a year or two.

The second primary symptom was the unusual presence of epicormic shoots (or basal sprouts): fast-growing, "adventitious" shoots (or suckers) sporting dense green foliage that appeared along the trunks or within the lower scaffold branches of the trees. These shoots represented a recovery method by which the tree was attempting to save itself. Over the course of the season, they were observed to grow as much as three or four feet. In effect, the tree was pouring nearly all of its remaining resources into a last-ditch effort to create a new leaf population in response to the dieback or death of its upper canopy, where nutrients could no longer reach. This latter symptom clearly indicated to arborists that the tree's roots were still healthy; thus, potential root problems or diseases could be ruled out as a source of the nutrient deficiency in the tree's canopy.[2]

Another clue, which remained unnoticed for several more months, was the presence of a number of very small, D-shaped holes, usually around one-eighth of an inch across. These were the exit tunnels created by adult emerald ash borer beetles upon their emergence from beneath the bark, where they had completed a year-long cycle of development. One had to look very closely to spot the holes, which could appear almost anywhere from just a few to many feet above the ground's surface. It is not surprising, therefore, that this clue was initially overlooked, even by experienced arborists. Still other clues would be observed only after sections of the tree's bark had been removed. But no one had yet proceeded that far in the investigation of this rapidly spreading malady.

THE DYING ASHES

Professional arborists working in the region had never seen such a concentration of ash tree decline and death, or the relative suddenness of its occurrence. Carl Dollhopf, the former head of nursery inspections and pest management for the Michigan Department of Agriculture, said, "In 37 years of doing this work, even through the loss of our elms, this is the worst problem I've seen."[3] (Dollhopf had retired in 1991). Trees that had been regarded as healthy in the previous year appeared suddenly stricken. Knowledge of the situation spread by word of mouth throughout the Michigan Arborists Association. By June 2001, arborists were calling David L. Roberts, Michigan State University Extension Specialist and District 11 Horticulture Agent for the Southeast Region (which includes Wayne, Oakland, and Macomb counties).

Roberts was no stranger to the problems of urban trees or to those who regularly cared for them. A native of Ohio, he had earned a PhD in plant pathology from Michigan State University (MSU) in 1982 and has spent his entire career at the institution. From 1984 to 1998, as director of the Department of Botany and Plant Pathology's Plant Pest and Diagnostic Clinic, he routinely oversaw some three thousand to five thousand diagnoses per year. In 1998, he was reassigned as extension specialist and district horticulture agent for the southeast region. Roberts was a frequent lecturer on all manner of plant-borne diseases and pests.[4]

At the urging of arborist Guerin Wilkinson of GreenStreet Tree Care in Ann Arbor, one of the first cases that Roberts investigated concerned about 80 ash trees at the Bradbury Parkhomes Condominium Association in Plymouth Township. Wilkinson had begun noticing the problem three years before but did not report it at that time.[5] Because all the ashes there exhibited similar symptoms, Roberts initially suspected an herbicide problem.[6] In June 2001, he enlisted Carl Dollhopf to help him conduct informal field surveys to determine the actual extent of the problem, and the two examined "at least a several square mile area," including Livonia and Plymouth, where "hundreds of trees" exhibited similar declining symptoms. Roberts immediately "rule[d] out cultural problems such as herbicide or fertilizer because the trees receive[d] different attention" and urged arborists, landscapers, and homeowners to "quit planting ash trees, at least in this localized area."[7]

Roberts's initial diagnosis was a disease called ash yellows. This illness is caused by a phytoplasma, a type of organism "remotely related to bacteria" but which produces symptoms "similar to viruses" and is principally spread by insects called leafhoppers. Phytoplasmas disrupt the plant's cellular physiology. In the case of ash yellows, they often turn the foliage a lighter shade of green and produce twig or branch dieback, but they can also cause stunted, off-color epicormic shoots, or "witches' brooms," along with other effects. Depending on the severity of the disease, not all the recognized symptoms might be present. But from Roberts's experience, he knew that the epicormic shoots did not look right as an indicator of ash yellows. As a result, he conservatively adopted "ash decline" as a descriptor of the malady. Roberts also knew that ashes could suffer from other illnesses and environmental factors, either singly or in combination, although individual afflictions, by themselves, less commonly proved fatal. He admitted that it might take "very involved investigative work" to determine what was affecting the area's ash trees.[8]

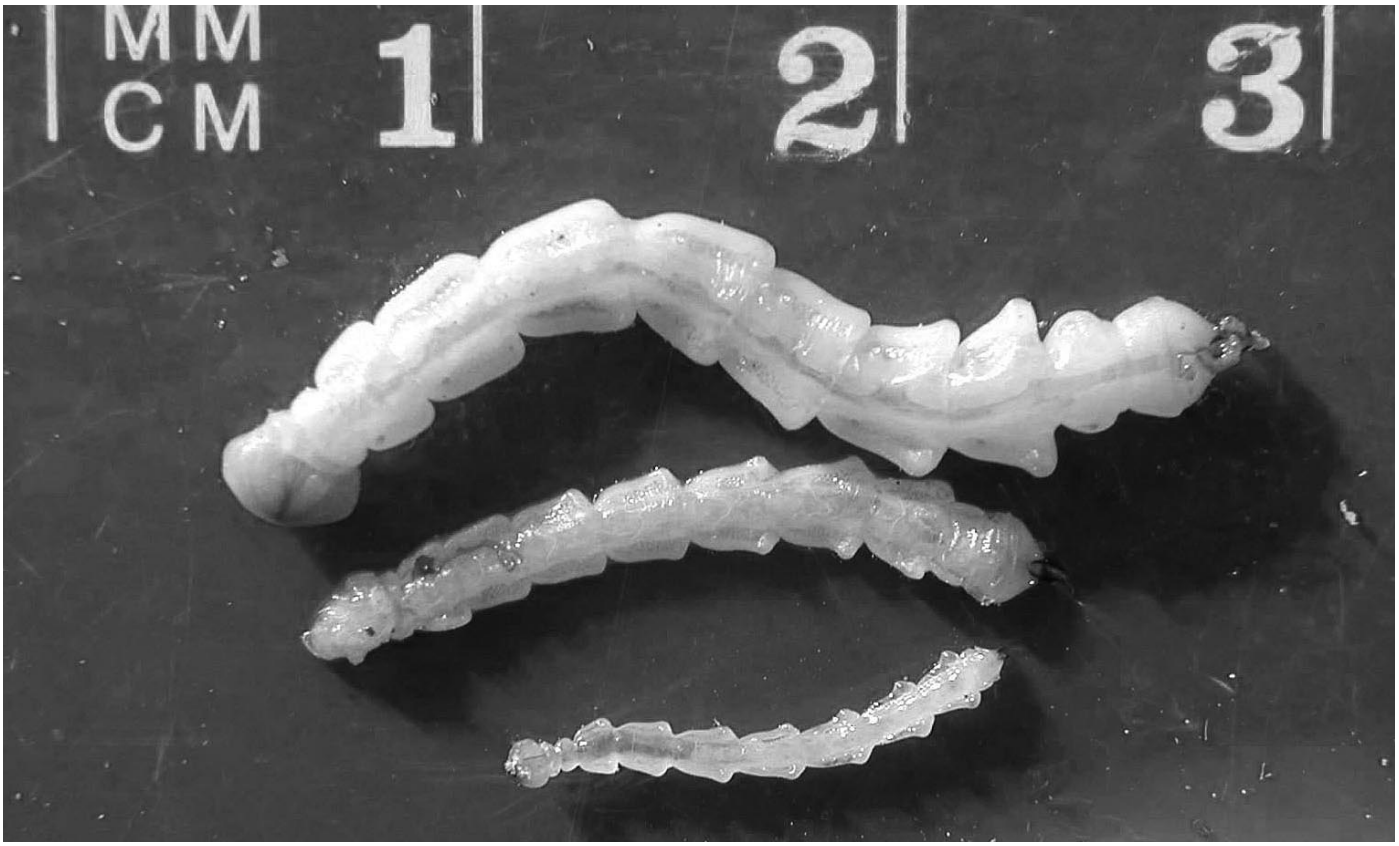
To confirm a diagnosis of ash yellows (and the presence of its phytoplasma), Roberts needed to run a sophisticated genetic test

DANIEL HERMS, THE OHIO STATE UNIVERSITY, BUGWOOD.ORG

An ash tree showing symptoms of crown dieback and basal (epicormic) sprouts.

DAVID CAPPAERT, MICHIGAN STATE UNIVERSITY, BUGWOOD.ORG

The adult emerald ash borer makes a D-shaped exit hole.



DAVID CAPPAERT, MICHIGAN STATE UNIVERSITY, BUGWOOD.ORG

These larval were collected from a tree in Maybury State Park, Michigan, on August 30, 2002, about six weeks after the public was first informed about the pest.

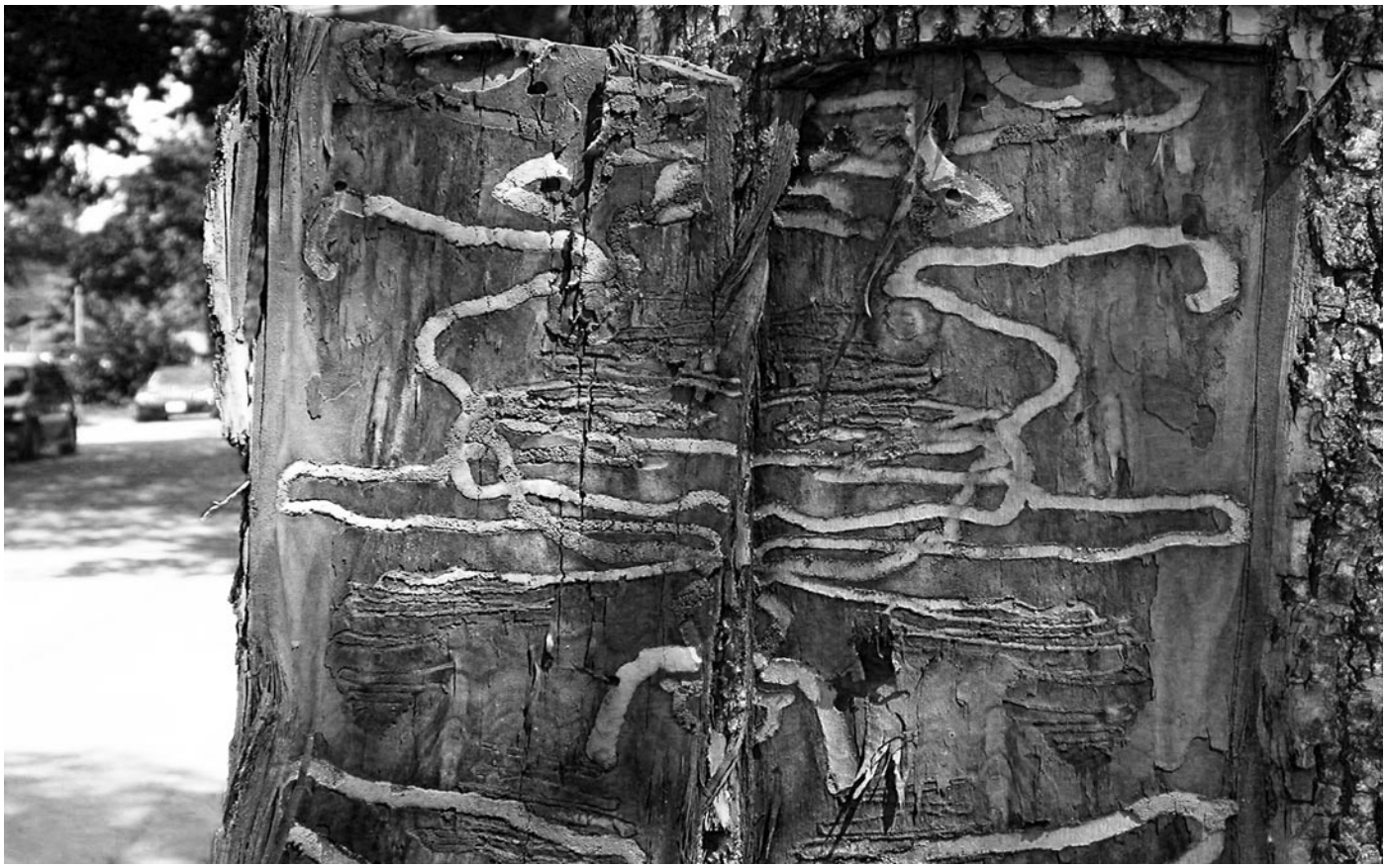
involving a polymerase chain reaction on a large number of samples. However, the best time to perform such a diagnostic test was in early spring, as the leaves were unfurling, which meant having to wait as much as eight or nine months for a probable answer. Furthermore, the MSU Plant and Pest Diagnostic Clinic lacked the necessary equipment to perform this sophisticated molecular test; the use of commercial laboratories like Agdia, Inc., would cost thousands of dollars that he did not have. This left Roberts in what he called the "diagnostic dilemma"—having a hypothesis he could not test and unable to make any direct progress toward a solution. By August he and Dollhopf had observed "very severe decline" among ash trees in an area exceeding 36 square miles and encompassing Livonia, Plymouth, and Plymouth Township, together with Wayne, Westland, Garden City, Dearborn, and Canton.[9]

But Roberts then realized that an additional way of testing for ash yellows lay at his disposal. If the disease was present, it might be isolated from live tissue collected from the lower trunk of an affected tree. As he had done in the past, Roberts sought help from his constituents and asked them to submit ash samples containing vascular tissue (phloem).[10]

A breakthrough occurred in September 2001, when a client of arborist Mike Meyers, owner of Shadetree Mechanic Tree Care in Canton, gave permission for the lower trunk of an infected ash tree to be dissected for the collection of samples for ash yellows analysis. When the bark was stripped away, it revealed the whitish larvae of an unknown beetle, along with the extensive damage made to the tree's vascular system: serpentine tunnels chewed through the inner bark and outer sapwood had progressively cut off the flow of nutrients to the tree's upper reaches and were responsible for the exterior symptoms of crown dieback. Photographs were taken of the feeding tunnels and larvae, and Roberts submitted at least one larval specimen to the MSU Plant Diagnostic Services Laboratory for analysis.[11] Roberts credited Myers for being "apparently one of the first arborists to believe that an insect was probably a major contributor to the ash decline problem" in southeast Michigan.[12]

Howard Russell, the insect diagnostician at the laboratory, could identify the larva only to the family Buprestidae (metallic wood-boring beetles) and probably to the genus *Agrilus*. Russell suspected it of being the domestic two-lined chestnut borer, *A. bilineatus*, but a more definitive identification could not be made at that time.[13] In North America, the dark gray two-lined chestnut borer was long recognized as the "most harmful and best-known species of the genus," which tended to favor Russell's diagnosis.[14] Unbeknownst to either Russell or Roberts, inspectors from the Michigan Department of Agriculture had also noted the appearance of D-shaped emergence holes in the bark of ash tree nursery stock several years before the outbreak in 2001, but they too had interpreted the D-shaped holes as having been made by *A. bilineatus* and did not pursue it further.[15]

Roberts, however, remained somewhat skeptical of the diagnosis because nothing in the literature described ashes as a recognized host to *A. bilineatus*. The two-lined chestnut borer, as its name implied, had once fed primarily upon American chestnuts (*Castanea dentata*), but later "became an important pest of oaks…after the introduction of chestnut blight" had caused the demise of its primary host.[16] One subspecies of the beetle is known to feed upon beeches (*Fagus spp*.) as well as ironwood, a tree in the birch family (*Betulaceae*).[17] Both oaks (*Quercus spp.*) and beeches belong to the



EDWARD CZERWINSKI, ONTARIO MINISTRY OF NATURAL RESOURCES, BUGWOOD.ORG

A serpentine feeding gallery excavated by the emerald ash borer larva beneath ash tree bark. D-shaped exit holes are also visible.

same family (*Fagaceae*) as the chestnut, which seemingly explains the relative ease with which *A. bilineatus* was able to shift its host preference from chestnuts to oaks. But if the larvae found in Michigan's ash trees matured into adults of *A. bilineatus*, then this would represent an even greater shift of that beetle's host preference—to a completely different tree family. Thus it became imperative to rear these unknown larvae into identifiable adults.

Taking a suggestion from his entomologist colleague David R. Smitley, an MSU professor and landscape industries extension specialist, Roberts collected samples of larvae and wood from infected ash trees and established conditions at his lab that would enable the larvae to mature into adults, a process requiring months.[18] Independent of Roberts, Carl Dollhopf likewise attempted the same thing from ash tree samples collected at his home in Westland. He cut four foot-long ash branches and kept them in a metal can in his garage over the winter. He brought the container into the house after the weather warmed up, where it could be monitored regularly.[19]

On January 25, 2002, Roberts convened the first public forum about the ash decline problem at an MSU Extension Service facility in Wayne, Michigan. Around 80 persons, including representatives of the Michigan Arborists Association, officials from the cities of Canton and Livonia, and master gardeners, were invited to hear the latest research into the ash decline problem. They were briefed on the discovery and rearing of the beetle larvae, along with other possible causes of the decline, including the pressing need for a comprehensive ash yellows diagnostic survey, to determine whether that disease was responsible for the widespread ash mortality. From that meeting, Roberts secured more than $6,000 in funding from his clientele to support the forthcoming ash yellows analysis.[20]

Roberts conducted the survey in late April to May 2002, and submitted roughly 65 ash leaf samples from a broad area encompassing the Wayne County epicenter to the research firm of Agdia, Inc., for polymerase chain reaction analysis.[21] Of those samples, only five tested positive for ash yellows disease. But Roberts had deliberately gathered two of those positive samples from near Ann Arbor—a locality then well outside the known ash decline region—which reduced the incidence of ash yellows to only three occurrences within the core area. This remarkably low incidence of disease completely overturned what many scientists and regulatory officials had come to believe was the cause of ash decline.[22] Furthermore, it greatly strengthened the hypothesis that the beetle larvae were the leading causal factor.

During March and April 2002, Roberts collected additional ash logs from the Novi area for the rearing of larvae, eventually accumulating around twenty in his lab. While collecting samples, he noticed another exterior symptom of the infestation—enhanced woodpecker activity, in the form of small but deep holes gouged into the trees' bark. The birds had evidently become adept at detecting the movements of larvae beneath the bark and extracting them through concentrated drilling.[23] This observation was readily confirmed and has since become another hallmark of the ash borer infestation.

THE MYSTERIOUS BEETLES

Finally, in late May 2002, the first specimen of an adult beetle emerged from an ash log in Roberts's lab. It was not the two-lined chestnut borer, a drab insect. These adult beetles had a brilliant bronze to golden green body and darker, metallic emerald wing

covers (elytra). Each was slender and elongated, shaped like a bullet roughly one-half inch long, with a rather blunt head and a tapered abdomen and elytra. They were unquestionably a species of *Agrilus*, but now the question became, exactly which one?

To be sure he was retrieving the same insect from all of his ash samples, Roberts waited until June 14 to bring his first specimens (both females) to Thomas Ellis, MSU Extension entomologist, who in turn gave them to Gary Parsons, coleopterist and taxonomist at the Department of Entomology. Parsons used a comprehensive key to species of North American *Agrilus* but was unable to determine their identity. Roberts's beetles were evidently unlike anything else known from Michigan, or from North America as a whole, leading Parsons to suspect that they were an introduced species. He persuaded a former colleague, entomologist Richard Westcott, a buprestid beetle expert with the Oregon Department of Agriculture, to help; Westcott required one or more male specimens to examine the beetle's genitalia before an identity could be made. On June 24, Roberts brought in five additional beetle specimens, including two males, and showed them to David Smitley, who also concluded that they were not native to Michigan. They then gave the beetles to Parsons, who promptly dispatched the male specimens to Westcott.[24]

An adult emerald ash borer beetle grows to approximately one-half inch long.

Acting under the assumption that the beetles were an exotic forest pest, and following standard protocol, a few other specimens were then submitted to Robert Carlson and Natalia Vandenberg of the Systematic Entomology Laboratory at the U.S. Department of Agriculture's Agricultural Research Service in Washington, D.C. They compared the specimens with ones from the Smithsonian Institution's National Museum of Natural History insect collection, without success. Other U.S. experts consulted could not identify the beetles; however, all agreed that the specimens were exotic and probably of Asian origin.[25]

On June 30 Westcott e-mailed a description and digital photos of the beetles to coleopterist Eduard Jendek of the Institute of Zoology, Slovak Academy of Sciences, at Bratislava, Slovakia. Jendek was a noted authority on Eurasian buprestids who in 1994 had revised the genus *Agrilus* and determined the synonymy of *A. planipennis* with three other described Asian species or subspecies.[26] On July 1, he tentatively identified the specimens as *A. planipennis* but required actual specimens for a positive identification. Using specimens supplied by Carlson, on July 9 Jendek confirmed the beetles as *A. planipennis* Fairmaire (1888).[27]

The native range of *A. planipennis* encompasses northeastern China, Taiwan, and Japan, although additional specimens have been reported in Mongolia, Korea, and the Russian Far East. Recognized host plants of the beetle in China are two species of ash trees, *Fraxinus chinensis* (including two varieties) and *F. mandshurica*. In Japan, however, a much more diverse host plant assemblage that encompasses four genera (and species) of trees has been reported: a different variety of *F. mandshurica*, the Manchurian walnut (*Juglans mandshurica*) and the Japanese wingnut (*Pterocarya rhoifolia*), and an elm (*Ulmus davidiana*).[28]

But while regarded as a minor forest pest in both China and Korea, *A. planipennis* was never recognized as posing a severe threat to that extensive region's ash, walnut, wingnut, or elm trees. Only during sporadic outbreaks was *A. planipennis* known to kill stands of Chinese ash trees. It appeared likely (and has since been confirmed) that one or more biological controls, in the form of predators or parasites, as well as an evolved form of host plant resistance, largely protected Asian species of ash trees from more severe depredations by the beetles. In America, the lack of any such natural enemies enabled the beetle population to grow unchecked. The search for biological controls, and the resulting attempts to apply them to help combat the spread of the emerald ash borer in North America, would become a principal thrust of the investigations pursued in coming years by entomologists and forest researchers alike.

WHAT'S IN A NAME?

After Roberts had presented his first beetles to the entomology department, he invited Smitley to inspect the ash tree damage firsthand in western Wayne County on June 17, 2002. Smitley, in turn, invited MSU forest entomologist Deborah G. McCullough. Near the Starbucks coffee shop at the intersection of Haggerty and 8 Mile Road, the trio readily found evidence of borer damage, even though Roberts had not examined those ash trees beforehand.[29] Convinced by what they saw, the entomologists immediately decided on a second inspection tour, this time involving state regulatory officials. Organized by Smitley, five entomologists (representing MSU, the state's Department of Agriculture and Department of Natural Resources, and the USDA Animal and Plant Health Inspection Service, or APHIS), met on June 25 with Roberts in Novi and Canton, where he showed them afflicted ash trees. Before their arrival, the officials had been somewhat skeptical that a nonnative wood borer could be the cause of the widespread ash decline. But as Smitley later recalled, after seeing the new larval galleries being formed in otherwise healthy ash trees, all were convinced that this must in fact be an exotic pest.[30] At that same gathering, Carl Dollhopf presented the group with seventeen adult beetles he had reared.[31] Beetles were also reportedly observed and collected for the first time from within the core area itself.

The trip had given the entomologists their first direct encounter with the high rates of ash mortality found within the area's cities and townships. During the visit, forest entomologist Deborah McCullough sensed that something indeed was very wrong. That night at dinner, she told her husband, wildlife biologist John McCullough, "This is going to be a bad thing. You watch."[32]

Shortly afterward, Michigan Department of Agriculture inspectors, initially led by Roberts, surveyed a minimum of 25 sites in each of 13 counties. By mid-July, they found evidence of the borer in five counties: Wayne, Livingston, Oakland, Macomb, and Washtenaw; a sixth, Monroe County, was added in September. As the entomologists later recorded, both they and the regulatory officials were "staggered by the extent of the dying and declining ash trees in landscapes and forested areas surrounding Detroit" that likely exceeded a thousand square miles.[33] Thus, it was clear to entomologists and foresters that this insect had "the potential to cause economic and ecological damage to ash on a scale similar to the impacts of invasive pests on [the] American chestnut and American elm."[34]

Though confident that a formal identity would soon be secured, researchers also realized that a uniformly accepted common name

DAVID CAPPAERT, MICHIGAN STATE UNIVERSITY, BUGWOOD.ORG

These trees with epicormic shoots were photographed in Novi, Michigan, on August 10, 2002.

for the pest must be chosen quickly. Announcements of the exotic insect's presence in southeastern Michigan as the leading factor behind the ash decline problem would soon capture media attention. Without an established common name, members of the press would make up their own, and confusion would surely result. The entomologists evaluated several leading adjectives, describing the beetle's color (e.g., emerald, green, metallic green), host plant (ash), probable origin (Asian), feeding habits (borer), and taxonomic relationships (*Agrilus* sp., buprestid). From these possibilities, the three-word name "emerald ash borer" emerged as the group's favorite. This proposed common name was submitted by Westcott and Natalia Vandenberg of the USDA to the Entomological Society of America, which readily accepted it as official.[35] As a result, the innocuous-looking beetle from Peking (now Beijing)—originally named and described by French entomologist Léon Fairmaire in 1888—entered the lexicon of world entomology as emerald ash borer, with the abbreviation EAB.[36]

During this same month, McCullough and Roberts prepared the first formal, published announcement concerning the pest's discovery, identification, and life-cycle features. *Pest Alert NA-PR-07-02* was nationally distributed by the Forest Service. A series of color photographs depicted the adult beetle (in relation to a U.S. penny for scale) and its late-stage larva. Diagnostic symptoms of EAB infestation included serpentine galleries, D-shaped exit hole, bark split above the larval gallery, and crown or canopy dieback along with epicormic sprouts. *A. planipennis*'s native range, and a list of Asian as well as domestic host plants, were likewise described. The alert somberly noted that, whether stressed or seemingly healthy, ash trees as small as 5 centimeters in diameter, but as large as "saw-timber sized trees," had been killed by the beetle.[37]

ACROSS THE RIVER IN CANADA

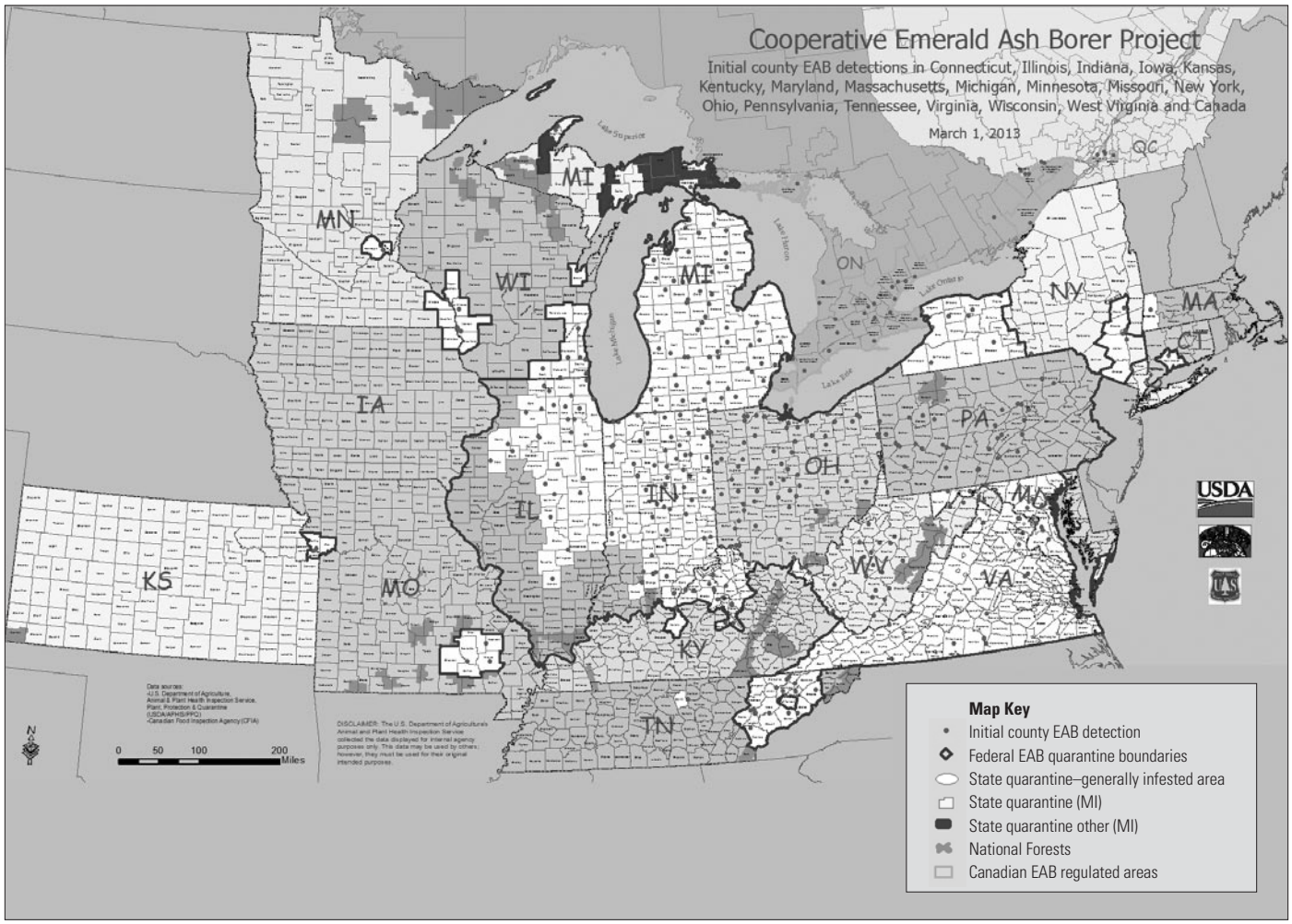
McCullough was worried that the invasive species might also be found across the Detroit River in the adjoining city of Windsor, Ontario. Given the ash borer's robust population density in the metropolitan Detroit area, the probability seemed high. She alerted Taylor Scarr, provincial forest entomologist at the Ontario Ministry of Natural Resources, of the possibility and urged a prompt survey of Essex County ash trees. At around the same time, Roberts came to a similar realization. When he inspected some ash trees growing near the casinos located immediately across the river on July 4, 2002, he found the identical effects of crown and canopy dieback and epicormic shoots, which indirectly confirmed the borer's presence.[38]

In response to McCullough's alert, three Canadian forest health specialists, Edward Czerwinski and Daniel Rowlinson of the Ontario Ministry of Natural Resources, and Douglas Lawrence of the Canadian Forest Service, made a preliminary inspection of ash trees in the Windsor area on July 10. Finding dead and dying trees, the researchers also collected similar metallic green beetles, which were forwarded to a federal laboratory in Sault Ste. Marie, Ontario. Because they could not be identified there, the beetles were sent to insect taxonomist Bruce Gill of the Canadian Food Inspection Agency in Ottawa, who in turn forwarded them to Richard Westcott, who confirmed their identity on August 7.[39] The emerald ash borer infestation had become a matter of international consideration.

THE STATE TAKES ACTION

Concurrently, back in the United States, events were moving rapidly toward a major public announcement about the pest, along with a planned quarantine on all ash products that originated from the five infested counties. The entomologists who had inspected the core area were soon appointed members of the Michigan Invasive Species Task Force, which consisted of government and university scientists, forest health specialists, and state and federal regulatory officials. The group met for the first time on July 10, 2002, where they presented reports concerning multiple aspects of the problem and began to craft an initial response.[40]

On July 16, the Michigan Department of Agriculture, representing both state and federal officials, formally announced "the discovery and identification of a new exotic pest from Asia—*Agrilus planipennis* or the Emerald Ash Borer" then affecting ash trees in the five southeastern Michigan counties. Agricultural officials simultaneously issued "a quarantine on all ash trees and timber products" that prohibited the movement or removal of ash trees, branches, logs, and firewood from the affected area, unless certified by the state agency. Only ash trees that had been cut and chipped into pieces one-inch square or smaller were allowed to be removed, since borer larvae or pupae could not survive in those pieces. Spokesman Kenneth Rauscher, director of the state agency's Pesticide and Plant Pest Management Division, explained the basis for issuing the quarantine and expressed confidence that the state was "doing everything possible to control and prevent



WWW.EMERALDASHBORER.INFO

As of March 1, 2013, the emerald ash borer could be found in eighteen states (Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, Wisconsin, and West Virginia) and two Canadian provinces (Ontario and Quebec).

the spread of this new invasive species and minimize the impact on the state's ash trees and nursery and landscape industries." A toll-free emerald ash borer telephone hotline was established for people outside the five counties to report any signs of the pest. The Michigan Department of Agriculture and the Forest Service launched new websites that used keyword links such as "ash borer." A press conference was scheduled for the following day in Northville, Michigan.[41]

Located in northern Plymouth Township, Northville was chosen for its proximity to the original site of the ash decline problem. After waiting months for answers as to the underlying cause, members of the press were now promised a "firsthand look at this pest and its damage." The pathway leading to the beetle's identification, its native range throughout eastern Asia, and annual life-cycle were described, along with its potential consequences for the region's forest and landscape ash trees. EAB, they were told, appeared to be a more efficient tree killer than Dutch elm disease and was already more widespread than the Asian longhorned beetle, another forest pest recently introduced into a few eastern and midwestern U.S. cities. Rauscher estimated that the ash borer had been established in the area for at least the past five years. It was likely transported to the region (in immature form) via wooden packing materials. Delay in its recognition was largely attributed to the assumption that ash yellows disease was responsible for the widespread decline. A lack of natural enemies was considered one of the probable reasons for the EAB's unchecked, explosive growth, and recommendations on pesticide applications were offered for homeowners and businesses.[42]

This press conference also marked the date, in McCullough's memory, when "all hell broke loose."[43] To her, the press conference marked the "official" start of the fight against the ash borer and a permanent change for her career.

WHY WAS THE EAB NOT RECOGNIZED SOONER?

In addition to the mixture of human errors and neglect documented above, other factors help to explain why the emerald ash borer's presence in southeastern Michigan was not detected sooner. One must also consider the location where the outbreak is believed to have begun. The principal cities and townships lying to the west of Detroit are heavily urbanized, largely characterized by lower-middle class neighborhoods and a predominantly blue-collar workforce. Urban tree care was not high on their list of priorities. The sight of a dying tree on property they did not own would likely have been met with indifference or the assumption that a landlord, or local public official, would deal with it.

By contrast, had the ash borer infestation begun in an upper-middle-class neighborhood, with its higher percentage of individual homeowners, the situation might have been different. A tree's

unexpected decline or death might have caught a homeowner's attention more readily, with a greater likelihood that a personal expenditure of time or financial resources might have been made in an attempt to find out why or what else might be done about it. But regardless of where the ash borer established a foothold in greater Detroit, the indifference to the dying trees on the casino-owned land in Windsor and local nursery workers' failure to question afflicted stock were contributing factors to its spread.

Location *is* a factor, but for a different economic reason. Many types of invasive species like the EAB first become established in urban ports of entry. Such was the case for many other insects and plant pathogens before imported nursery stock was regularly screened. In recent years, however, various forms of solid wood packing material, along with pallets and crates, have become inadvertent sources of invasive forest insects.[44]

Another contributing factor was hubris. A significant portion of the nation's urban ash tree population had been planted starting several decades ago in response to major losses of the popular urban tree the American elm (*Ulmus americana*). Those losses stemmed from outbreak of the fungal pathogen (*Ophiostoma ulmi*) that causes Dutch elm disease, an ailment that was spread by the introduction of another invasive species, the small European elm bark beetle (*Scolytus multistriatus*), still earlier in the twentieth century.[45] In their place, ash trees were frequently chosen because of their hardiness, rapid growth rates, and general freedom from known pests such as the Gypsy Moth (*Lymantria dispar*). Through 1994, not one of 57 recognized species of *Agrilus* beetles inhabiting the northeastern United States was known to use ash as its host.[46] At the same time, several ash varieties became particularly popular among arborists and landscapers, including the "Marshall Seedless" green ash cultivar, introduced in the 1940s, and the "Autumn Purple" white ash cultivar, widely planted in the 1980s and 1990s.[47] Because they were not planted as uniformly or extensively as American elms and comprise more than a single species, ashes do not represent a strict monoculture as complete as that formerly occupied by the American elms. But planting ash trees in clusters left them vulnerable to an invasive pest with no natural predators in North America. As Roberts lamented in September 2001 about the overplanting of native ashes, "We're back in that situation [again] and we're going to pay for it."[48]

The bottom line is that a host of potential observers, stretching from scientists and government regulatory officials down to ordinary citizens, were not astute enough in watching and understanding the unfolding ash decline problem and failed to communicate their findings to others. Those whose jobs it was to notice such things apparently did so, although none took decisive follow-up actions.[49] Compounding matters, not one but two widespread misconceptions operated in concert and prevented a correct diagnosis from being made. Regulatory officials did not properly connect the two independent lines of evidence suggesting the alien beetle's presence. Neither ash yellows disease nor the two-lined chestnut borer was responsible for the spreading malady, although external symptoms noted on the area's ash trees strongly resembled those potentially caused by these two agents. Professional entomologists were not initially consulted, despite the mistaken inference that *A. bilineatus* had dramatically shifted its host preference from oaks to ashes. That gave the beetle several years to spread across western Wayne County and beyond. For entirely different reasons, residents of the afflicted townships were unaware or unconcerned and lacked the means or desire to act in any way that might have made a difference. Only when the ash decline problem at last reached some indefinable "critical mass" in the summer of 2001 did the situation finally change and the first investigations begin. Then, it took almost twelve months of investigative work, performed almost exclusively by David Roberts, to demonstrate conclusively that an exotic forest pest was the underlying cause of ash decline in southeastern Michigan and Ontario.

There are promising signs that the lesson has been understood, and that the message is gradually being spread. To borrow from Thomas J. Campanella's history of the American elm, what happened to the ash was in part "human design that stacked nature's deck against the tree" and hastened its decline. The history of urban forestry in the United States has shown that the practice of overplanting and "favoring any one species to excess" can lead to environmental catastrophe.[50] Similar sentiments have now been expressed regarding the continued plantings of ash trees in urban settings, and alternatives are now recommended.[51] As Campanella also noted, "The mantra of urban forestry today is sustainability and species diversity, and it is a wise one indeed."[52] □

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NOTES

1. David L. Roberts, "Ash Yellows/Decline Update," *Crop Advisory Team Alert*, August 24, 2001, 1–2. This bulletin is a publication of MSU Extension.
2. David L. Roberts, "Ash Yellows or Ash Decline or…?", *Landscape Alert*, June 1, 2001, 4–6; Roberts, "Ash Decline in Michigan," October 2001, accessed October 25, 2010, http://www.anr.msu.edu/robertsd/ash/ decline.pdf, plus other linkages. I am grateful to Roberts for having provided continuous access to his websites, long after he has ceased to work on the EAB problem. Joy Landis and her assistant, Erica Haney, furnished copies of Roberts' articles from *Landscape Alert* and other MSU Extension publications.
3. Carl Dollhopf, quoted in Janet Macunovich, "The Trouble with Ash Trees," *Detroit News*, September 4, 2001, 1-C, 5-C.
4. Roberts, e-mail message to author, November 2, 2010; Roberts, unpubl. "Curriculum Vitae."
5. Roberts, interview with author, August 18, 2010 (handwritten notes in possession of author); Marty Hair, "Ash Trees in the Area Are Mysteriously Dying," *Detroit Free Press*, September 3, 2001, 3-A, 9-A. See also Hugh McDiarmid, Jr., "Chasing Down Beetles Consumes Pathologist," *Detroit Free Press*, March 27, 2003, 8-B.
6. David L. Roberts, "Ash Yellows or Decline: Part 2," *Landscape Alert*, June 22, 2001, 4.
7. Ibid.
8. Roberts, interview; Roberts, "Ash Yellows or Ash Decline or . . . ?," 4. He noted that "[t]he term 'decline' is normally ascribed to situations in which we are uncertain of the primary causal factors."
9. Roberts, "Ash Yellows/Decline Update," 1.
10. Roberts, "Ash Yellows/Decline Update," 1. Roberts declared the "lower trunk of living trees" as the "best location for detection of the phytoplasma" and offered his advice on collecting samples. "Otherwise," he noted, "we will have to wait until spring for a possible survey of foliage," 1.

11. A larval specimen, Plant Diagnostic Services Lab case 20013301, collected Sept. 7, 2001, has been preserved in the A. J. Cook Arthropod Research Collection, Department of Entomology, MSU. It was tentatively identified as "at or near two-lined chestnut borer." Gary Parsons, collections manager, e-mail message to author, December 8, 2010.
12. Caption to Fig. 40, Roberts, "Ash Trees Decline," 13, accessed October 24, 2010, http://www.anr.msu.edu/robertsd/ash/decline.html; Roberts, interview. Not coincidentally, "Mike Meyers, Shadetree Mechanic," headed the list of "individuals and groups" whom Roberts later thanked in his "Acknowledgments" for having "participat[ed] in research" upon the ash decline problem. Roberts, ibid., 11. See also Marty Hair, "Borers Attack Ailing Ash Trees," *Detroit Free Press*, September 21, 2001, 1-H, 5-H.
13. Parsons, e-mail message to author, November 12, 2010. Parsons noted the lack of diagnostic keys to larvae beyond family level, with the only example given (in the leading text) being that of the two-lined chestnut borer, *A. bilineatus*, a common Michigan species. He expressed "doubt that [Russell] had any way of believing or suspecting that this might be an invasive species since he had nothing to identify or compare it with…. So that was the initial diagnosis."
14. Richard E. White, *A Field Guide to the Beetles of North America* [The Peterson Field Guide Series] (Boston: Houghton Mifflin, 1983), 170. White further notes that "[a]ttack by this beetle usually starts at topmost branches, which may be killed the 1st year; larger limbs are killed the 2nd year, and the entire tree may die the 3rd year," which closely followed the pattern witnessed on the area's ash trees. See also Robert A. Haack and Daniel M. Benjamin, "The Biology and Ecology of the Two-lined Chestnut Borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), on Oaks, *Quercus* spp., in Wisconsin," *Canadian Entomologist* 114 (1982): 385–396; and [Haack and Robert E. Acciavetti], "Two-lined Chestnut Borer," *Forest Insect and Disease Leaflet* 168 (Washington, DC: USDA Forest Service, 1992).
15. Roberts, e-mail message to author, November 15, 2010. He wrote, "Unbeknownst to me, inspectors of the MDA [Michigan Department of Agriculture] had witnessed the D-shaped emergence holes in nursery ash trees for some time and erroneously concluded it [sic] to be caused by the TLCB. I learned this from the inspectors when I conducted tours of infested areas…after my own discovery was made known." Roberts's statement was confirmed by Carl Dollhopf, former head of nursery inspections for MDA. Dollhopf, telephone conversation with author, December 11, 2010.
16. Andrea C. Anulewicz, Deborah G. McCullough, and Deborah L. Miller, "Oviposition and Development of Emerald Ash Borer (*Agrilus Planipennis*) (Coleoptera: Buprestidae) on Hosts and Potential Hosts in No-choice Bioassays," *The Great Lakes Entomologist* 39 (2006): 99–112, quote on 100. On the smaller European elm bark beetle and the transmission of chestnut blight, see Whiteford L. Baker, *Eastern Forest Insects*. U.S. Department of Agriculture Forest Service Miscellaneous Publication No. 1175 (Washington, DC: Government Printing Office, 1972), 235–237. For a complete contextual study of the American chestnut tree, see Susan Freinkel, *American Chestnut: The Life, Death, and Rebirth of a Perfect Tree* (Berkeley, Los Angeles, and London: University of California Press, 2007).
17. W. S. Fisher, "A Revision of the North American Species of Buprestid Beetles Belonging to the Genus *Agrilus*," *United States National Museum Bulletin* 145 (Washington, DC: Government Printing Office, 1928), 113–119. Fisher noted (118) that *A. bilineatus* "will probably attack any of the oaks, and becomes very injurious to trees which have been weakened by other insects, plant diseases, or climatic conditions."
18. David Smitley, e-mail message to author, December 6, 2010, wrote, "When Dave said he was wondering if a borer was involved in the decline of ash trees in the Canton area, I suggested that he cut some branch and trunk samples in the fall and bag them to see what emerges the following spring. It is my understanding that he did this with the cooperation of an arborist or that Carl Dollhopf arranged this with an arborist."
19. Dollhopf, telephone conversation.
20. Roberts, interview; e-mail message to author, November 15, 2010; "Ash Decline in Michigan," 2–3. For a partial account of the forum, see Janet Macunovich, "Huge Task of Isolating Remedy for Dying Ash Trees Is Under Way," *Detroit News*, February 9, 2002, 8-E, 9-E.
21. Marty Hair, "Program Will Try to Pinpoint Decline of Ash Trees," *Detroit Free Press*, April 18, 2002, 1-B.
22. Roberts, interview; e-mail message to author, November 15, 2010; Roberts, "Discovery of the Emerald Ash Borer: A New Exotic Pest for Michigan and North America," *Landscape Alert*, July 26, 2002, 2–4; McDiarmid, "Chasing Down Beetles Consumes Pathologist." Roberts's test results (in storage) could not be directly examined. But from the reported sample size and total outlay for analysis, testing for ash yellows evidently cost around $100 per sample.
23. On the woodpeckers, see "Ash Decline in Michigan," 3, in which Roberts noted that "the amount of woodpecker activity seems highly correlated with the amount of decline in the tree." He suspected that downy and hairy woodpeckers were the probable (but unseen) agents.
24. Smitley, e-mail message to author, December 6, 2010; Parsons, e-mail messages to author, November 12 and December 8, 2010. In the latter, Parsons confirmed the acquisition of five beetle specimens in the Arthropod Research Collection, each of which bears the date range June 14–24, 2002, that were reared from larvae collected by Roberts at Novi, Michigan.
25. Robert A. Haack et al., "The Emerald Ash Borer: A New Exotic Pest in North America," *Newsletter of the Michigan Entomological Society* 47, nos. 3&4 (September 2002): 1–5; Deborah G. McCullough, interview with author, August 18, 2010 (handwritten notes in possession of author). Specimens were sent to Henry Hespenheide of the University of California at Los Angeles under the initiative of Andrew J. Storer, Michigan Technological University.
26. Eduard Jendek, "Studies in the East Palaearctic Species of the Genus Agrilus Dahl, 1823 (Coleoptera: Buprestidae). Part I." *Entomological Problems* 25 (1994): 9–25.
27. Haack et al., "New Exotic Pest," 2.
28. Ibid. See also Academia Sinica, Institute of Zoology, "*Agrilus marcopoli* Obenberger," in *Agricultural Insects of China* (Part I) (Beijing: Agricultural Publishing House, 1986), 445; C. Yu, "*Agrilus marcopoli* Obenberger," in *Forest Insects of China*, 2nd ed., ed. Gangrou Xiao (Beijing: China Forestry Publishing House, 1992), 400–401. *A. marcopoli* is the name by which *A. planipennis* was chiefly known, before its synonymy was established by Jendek.
29. Roberts, e-mail message to author, December 23, 2010.
30. Smitley, e-mail message to author, December 6, 2010. The contingent of five officials almost certainly consisted of Smitley, McCullough, James Lonchar (MDA), Roger Mech (MDNR), and Jerry Wheeler (USDA-APHIS). Two days later (June 27), a somewhat different contingent, now including Andrew J. Storer (Michigan Tech) and David McKay (USDA-APHIS), undertook a similar visit. Storer, e-mail message to author, January 25, 2011.
31. Dollhopf, telephone conversation. He was the source of other beetles that were subsequently sent to entomologists at the USDA/APHIS (and elsewhere) for identification.
32. McCullough, interview; McCullough, quoted in Marty Hair, "Lassoing the Green Fiend," *Detroit Free Press*, January 19, 2004, 1-C, 3-C.
33. David Cappaert et al., "Emerald Ash Borer in North America: A Research and Regulatory Challenge," *American Entomologist* 51 (Fall 2005): 152–165, quote on 152; Haack et al., "New Exotic Pest," 4; Roberts, e-mail message to author, November 15, 2010. The latter noted that "[t]he difference in attention" paid to the problem, before and after the beetles' emergence, "was astonishing."
34. Cappaert et al., "Research and Regulatory Challenge," 154.
35. Hanck et al., "New Exotic Pest," 1.
36. L. Fairmaire, "Notes sur les Coléoptères des environs de Pékin," 2e Partie, *Revue d'Entomologie* 7 (1888): 111–160; "*Agrilus planipennis*," is on page 121.
37. Deborah G. McCullough and David L. Roberts, "Emerald Ash Borer." *Pest Alert NA-PR-07-02* (Newtown Square, PA: USDA Forest Service, Northeastern Area, State and Private Forestry, July 2002). Revised editions were issued in September 2002, January 2004, and September 2008.
38. McCullough, interview; Roberts, interview. Which individual acted first, and whether one might have influenced the other, can no longer be determined. Apparently, Roberts did not find actual beetles on the infected trees, as he returned no specimens.
39. Haack et al., "New Exotic Pest," 2.
40. Cappaert et al., "Research and Regulatory Challenge," 152. The entities represented included MSU, Michigan Technological University (MTU), MDA, MDNR, USDA-APHIS, and the U.S. Forest Service. The task force itself was created under an initiative from the state's Invasive Species Emergency Response Plan.
41. MDA (Michigan Department of Agriculture), "New Exotic Pest Identified in Michigan's Ash Trees; State Issues Quarantine to Control, Prevent its

Spread." Press Release, July 16, 2002; last modified May 18, 2003; accessed Nov. 10, 2010, http://www.michigan.gov/mda/0,1687,7-125-1572_3628-44736—,00.html. In its 2002 *Annual Report*, the MDA's Pesticide & Plant Pest Management Division admitted that over "the past couple of years," "widespread decline and loss of ash trees…in southeast Michigan" was "first attributed…to a combination of disease, drought, and poor soils" by specialists at both MSU and the MDA. See "Emerald Ash Borer Eradication," 22.

42. MDA, "New Exotic Pest; State Issues Quarantine"; Marty Hair, "Tree-killing Pest Causes Quarantine," *Detroit Free Press*, July 17, 2002, 1-A, 8-A; Hair's sidebar, "Details on the Quarantine," ibid., 8-A.
43. McCullough, interview.
44. Ibid.; Therese M. Poland and Deborah G. McCullough, "Emerald Ash Borer: Invasion of the Urban Forest and the Threat to North America's Ash Resource," *Journal of Forestry* 104 (Apr./May 2006): 118–124, esp. 118.
45. The most complete account of the American elm and the introduction of Dutch elm disease is Thomas J. Campanella, *Republic of Shade: New England and the American Elm* (New Haven and London: Yale University Press, 2003).
46. N. M. Downie and Ross H. Arnett, Jr., *The Beetles of Northeastern North America*, 2 vols. (Gainesville, FL: Sandhill Crane Press, 1994), 1:758–772 (sub-family *Agrilinae*).
47. Poland and McCullough, "Invasion of the Urban Forest," 120.
48. Roberts, quoted in Hair, "Ash Trees…Mysteriously Dying," 9.
49. In an e-mail message to the author dated December 10, 2010, Roberts reiterated, "Several MDA inspectors related their sentiments during the time of the field tours that they always thought the D-shaped holes were caused by the [two-lined chestnut borer]. These folks had been seeing the D-shaped holes on nursery-inspected trees for several years and regrettably had not bothered to properly identify the insect."
50. Campanella, *Republic of Shade*, 165, 183; Therese M. Poland, "Twenty Million Ash Trees Later: Current Status of Emerald Ash Borer in Michigan," *Newsletter of the Michigan Entomological Society* 52 (April 2007): 10–14.
51. Bert Cregg and Robert Schutzki, "Recommended Alternatives to Ash Trees for Michigan's Lower Peninsula." *Michigan State University Extension Bulletin E-2925*, revised, January 2006. Some urban foresters have suggested removing healthy ash trees even before the first appearance of EAB is recorded in their municipalities. Ron Seely, "Small Bug Poised to Cause Big Tree Crisis," *Wisconsin State Journal*, October 21, 2010, 1-A, 10-A; and Seely, "City to Whittle Tree Options," *Wisconsin State Journal*, November 7, 2010, 1-C, 3-C.
52. Campanella, *Republic of Shade*, 183.