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# Assessing the Hazard of Emerald Ash Borer and Other Exotic Stressors to Community Forests

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**Abstract.** Exotic stressors such as emerald ash borer are an increasing concern to many communities across North America. One means of assessing the hazard these stressors may represent to a community's publicly managed trees is through an inventory of their street trees. The South Dakota Division of Resource Conservation and Forestry conducted street tree inventories in selected communities across the state and, from these data, have placed communities into stability categories based on the percentage of full stocking that each genera represents within the street tree population. The majority of surveyed communities are in the low stability category as a result of the dominance of green ash in their street tree populations.

**Key Words.** *Agrilus planipennis*; emerald ash borer; species diversity; stability; street tree inventories; street trees.

There is a growing list of exotic insects and pathogens that are current or looming threats to community forests throughout North America. This alphabet soup of exotic stressors, from ALB, Asian longhorned beetle (*Anoplophora glabripennis*), to SOD, sudden oak death (*Phytophthora ramorum*), follow in a long succession of insects and pathogens introduced onto this continent. Several of these new stressors have the potential to alter the forest landscape as dramatically as did chestnut blight (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma ulmi* and *O. novo-ulmi*) during the 20th century (Raupp et al. 2006). The fall of American elm (*Ulmus americana*) from its prominent status as "the street tree" was a tremendous loss to community forests because many Eastern and Midwestern cities were heavily planted with this tree (Campana 1999). The loss of elm has also had an impact on how communities manage their forest, but the lesson learned from the Dutch elm disease epidemic was the wrong lesson—not to plant elm; instead, the lesson that should have been gleaned was to limit dependence on a single species or genus (Kielbaso and Kennedy 1983).

Street trees are planted along the lawn area adjacent to streets, typically between the sidewalk and street. They are the primary focus for many community forestry programs and the resources for establishment, care, and removal of these trees comprise the majority of many city forestry budgets (Kielbaso et al. 1988). Although most of the community forest is situated on private property, the number of street trees can be substantial. There are approximately 60 million street trees in cities across the United States (Kielbaso 1990) and these trees account for approximately 10% to 20% of the total urban forest biomass (McPherson and Rowntree 1989).

Species diversity has been a goal of many street tree programs, but the value of diversity is not universally accepted. Cities have been described as visually disordered with the architecture and placement of buildings often designed with little regard to their surroundings (Trowbridge and Bassuk 2004). Street trees can provide a unifying and ordering element to this landscape (Arnold 1980), but having visual uniformity while providing species diversity has been problematic (Trowbridge and Bassuk 2004).

Biological diversity is regarded as the basis for ecological stability (Tilman and Downing 1994) and this has been given as the justification for diversity in street tree populations (McBride and Jacobs 1976; McPherson 1993). However, the concept that diversity achieves stability is not universally accepted (Kimmerer 1984), particularly within the confines of street tree populations (Arnold 1980). Richards (1982) commented on this by pointing out that species diversity per se would not result in stability if the trees were not adapted to the site conditions. Unfortunately, there are a limited number of tree species adapted to the harsh growing conditions found in many cities, a fact lamented early in the last century (Solotaroff 1911) and repeated to the present day. Simply increasing diversity is of little benefit if poorly adapted species are used merely to fulfill a quota.

The value of diversity to stability, as Rowntree (1998) points out, also depends largely how these terms are defined and the context in which they are used. In terms of a street tree management tool, diversity may be defined as the number of individuals representing a variety of species in different age classes (Sanders 1981) and stability as the low probability that the number of functional trees will decline to the point of disrupting management and diminishing the benefits they provide (Richards 1982). If too many street trees are affected by a lethal stressor, the high cost associated with the removal of these trees as well as the disruption to the operation of the city forestry department resulting from the sudden need to adjust priorities can be devastating to the city budget as well as the operations of the department responsible for these trees.

Thus, the goal becomes not necessarily diversity, because this effort may not improve stability, but instead limiting the use of a species to forestall disruptions to budgets if widespread losses occurred within a short time period. The concept of limiting the use of a species appears to have been first discussed by Barker (1975) who proposed a list of species for "liberal use" as street trees but not to exceed more than 5% of the total street tree population. He also suggested another category of "limited use" species whose use should be limited to no more than 2% of the total and a "candidate use" category that restricted use to less than 0.3%. Miller and Miller (1991) modified the criteria to reflect the limited number of species suitable to the urban environment and proposed that the liberal use species not exceed 10%, limited use species not exceed 5%, and candidate use species not exceed 2% of the street tree population. Clark and others (2003) incorporated this concept of limitation into their model of urban forest sustainability in which the vegetation resource is one of the components. The specific criteria they identified included an uneven age distribution and a diversity of species following a guideline of limiting a species' use to 10% of the entire street tree population.

This concept of limiting the use of a species is gaining renewed interest as a result of the relatively recent discovery of the emerald ash borer (*Agrilus planipennis*) in the Midwest. This close relative to the bronze birch borer (*A. anxius*) became established in southeastern Michigan, U.S. sometime during the 1990s, apparently arriving in ash packing material from Asia. The emerald ash borer appears to be a secondary stressor on native ashes (*Fraxinus* spp.) in Asia, but has become a primary stressor on ashes native to North America both in this country as well as when they are planted in Asia (Hermes et al. 2005). The insect has been responsible for the loss of more than 15 million ash trees in Indiana, Michigan, Ohio, and southeastern Ontario (Poland and McCullough 2006) with new established infestations such as the recent one in Illinois being discovered as detection efforts expand. The projected costs of removing infested ash trees, if the insect does become established across the United States in a scenario reminiscent of the removal efforts associated with Dutch elm disease, is estimated to be between $20 and $60 billion (Cappaert et al. 2005).

Much of the Midwest and Great Plains has a high presence of ash as street trees as well as on the adjacent private property. The concern in many communities, particularly those located on the Plains states such as South Dakota, is the potential effect the emerald ash borer will have on their street trees. The response to this threat should not be as simplistic as merely curtailing the use of ash in the landscape by substituting one species or genera for another, or communities will be only repeating the mistakes made with Dutch elm disease management. This already may be occurring with the shift in popularity from ash to the Freeman maple cultivars (*Acer* × *freemanii*) attributable in part to the widespread concern about the future of ash and the desire for another relatively fast-growing shade tree. Instead, the focus should be on categorizing community forests in regard to their stability in response to lethal stressors and then adjusting planting efforts to reduce this hazard over time, hazard being defined as the vulnerability of a forest to a particular stressor given that the stressor is present (Coulson and Witter 1984). The assumption here is that given international trade, a lethal stressor should be assumed for any given genera regardless of whether such stressor is present or even known at the time.

The South Dakota Division of Resource Conservation and Forestry has been collecting community street tree data for approximately 14 years. The intent of this project is to provide baseline data of the species, age, and condition of selected community forests across the state. One of the objectives was to determine our reliance on limited species. Although the emerald ash borer was not yet recognized as a threat when the project began, there were concerns about the possible loss of a key species, much as what began occurring in the state after the detection of Dutch elm disease in South Dakota in the late 1960s.

## MATERIALS AND METHODS

The project began with a preliminary survey of several smaller communities across the state from 1992 to 1994 to develop a sampling technique. The communities to be surveyed were selected through a two-way stratification procedure (Cochran 1977) with the two criteria being location and city size. The cities were divided into two strata, East River or West River. These are common designations in South Dakota that divide the state into areas east or west of the Missouri River. This boundary is more than a physical division of the state because the soils and climate, in terms of precipitation, differ on either side of the river (Hogan 1995). The communities were further stratified based on population with the three strata following the South Dakota Municipal League (2004) divisions into classes 1, 2, or 3 communities based on a population of 5000 or greater, 501 to 4999, and 500 people or fewer, respectively. The allocation to each stratum was proportional to population and the communities selected within each of the strata were random with this notable exception. The two largest communities in South Dakota, Sioux Falls and Rapid City, were excluded from consideration as a result of the resources required to conduct inventories in these larger communities. The survey included 34 of the 308 communities within the state. These communities have a population of 57,286 of the 501,665 South Dakota residents that live in incorporated municipalities (Table 1).

The data collected on each street tree had a dual purpose of providing communities with the information for the management of their street trees as well as providing the state with the information to determine the impact of lethal stressors to the state. Street trees were considered all trees within the road easement for each city and sidewalks usually delineated this boundary, but in communities lacking sidewalks, the appropriate distance, which varied among the communities, was measured from the center of the roads. The information collected on each street tree included location along the street, species, total tree height, tree diameter at 1.37 m (4.5 ft), canopy condition class, and presence of power lines among other attributes. Available planting spaces were also recorded with the assumed spacing of approximately 13.7 m (45.2 ft) and excluded sites that could not be planted as a result of pavement for either driveways or parking. Risk assessment was not part of the inventory, or Plant Health Care recommendations, because volunteers were used for the inventory effort and did not have the training to properly evaluate tree health or assess defects. The inventory system used for many of the communities was TreeKeeper Online designed and managed by the Davey Resource Group, a division of The Davey Tree Expert Company (Kent, OH). Many of the smaller communities, class 3, do not have their inventories in this system because the communities do not have enough street trees to justify the computer storage. Several of the class 2 also do not have the data available online because the communities have not expressed interest in using the information.

**Table 1. Surveyed South Dakota communities by municipal league population divisions and location in the state.**

| Class | East River (east or west of Missouri River) | West River |
|---|---|---|
| Class 1 | Brookings (18,504) | Spearfish (8606) |
| More than 5000 residents | Pierre (13,876) | |
| Class 2 | Canton (3110) | Eagle Butte (619) |
| Between 500 and 5000 | Clark (1285) | Murdo (612) |
| | DeSmet (1164) | Presho (588) |
| | Mobridge (3574) | Wall (818) |
| | Selby (736) | White River (598) |
| | Tripp (711) | |
| Class 3 | Andover (97) | Batesland (88) |
| Fewer than 500 residents | Bushnell (75) | Bison (373) |
| | Dolton (41) | Kennebec (286) |
| | Eden (97) | Wasta (75) |
| | Geddes (252) | |
| | Harrold (209) | |
| | Hitchcock (108) | |
| | Lake Nordon (432) | |
| | Montrose (480) | |
| | Naples (25) | |
| | Nunda (47) | |
| | Pickstown (168) | |
| | Ree Height (85) | |
| | Roscoe (324) | |
| | Stockholm (105) | |
| | Yale (118) | |

Master Gardeners, community members, South Dakota State University Cooperative Extension educators, Division of Resource Conservation and Forestry service foresters, and university students collected the inventory data. Inventory training was made part of the annual Master Gardener certification seminars and an orientation session was conducted with all volunteers at the beginning of each community inventory. Whenever possible, a service forester was assigned to a crew or would float among several crews to answer questions and check that accurate data were being collected. The data were initially collected on paper spreadsheets from which volunteers would later enter the data into an online database for South Dakota maintained by the Davey Resource Group. Data were later collected on iPAQs (Compaq, Houston, TX) to allow for more efficient data entry and to reduce the chances of error in data transfer.

## RESULTS

An error-free inventory, although a goal, is difficult to attain. This inventory project relied heavily on the efforts of community volunteers and Master Gardeners. They were responsible for the much of the data collection and entry. A random survey of streets within each of the communities revealed a range of errors. The most common was an incorrect address; ≈3.7% of the addresses in the random survey were incorrect, most often as a result of a corner house having its address on the other street or guessing wrong at an address for a house that did not have a street number identified on the mailbox or curb. These were insignificant errors for this study but can become a problem if a community inventory is used for scheduling tree work. Tree identification was also a source of errors. The random survey found ≈1.2% of the species were misidentified, usually confused with another species of the same genus. The error rate for the other attributes was much lower, most likely as a result of either the simple nature of data, power line present or absent for example, or the wide range of choices. Tree height, for example, was collected as only three choices, less than 9.1 m (30 ft), between 9.1 (30 ft) and 13.7 m (45.2 ft), and greater than 13.7 m (45.2 ft). The majority of the errors discovered in the random survey were made during data collection, not entry.

South Dakota street tree populations in the surveyed communities ranged from a low of 0.13 to a high of 2.41 street trees per capita. The average was 0.40 street trees per capita but with differences among and within the three community population classes (Table 2).

A total of 22,390 street trees representing 33 genera and 62 species were inventoried in the 34 communities included in the survey (Table 3). The most common species used statewide as a street tree is green ash at 35.3% of the total street tree population. The next most common is American elm (9.1%) followed by crabapple cultivars (*Malus* spp.) (7.7%), silver maple (*A. saccharinum*) (5.8%), and hackberry (*Celtis occidentalis*) (5.3%).

The ranking and species changed with community population size (Table 4). Green ash was still the most common species regardless of the population size of the community, but it became more abundant in the smaller communities. Siberian elms also became more abundant in these communities. Cottonwood (*Populus deltoides*) and Colorado blue spruce (*Picea pungens*), two species often prohibited from planting in larger communities, are common street trees in smaller towns.

The surveyed communities in South Dakota have slightly less than half of their green ash population with a diameter smaller 30.5 cm (12.2 in) (Table 5). American elm, as a comparison, has only 4.9% of their street population in the 2.5 to 30.5 cm (1 to 12.2 in) categories. Two other most common street trees, silver maple and hackberry, had only approximately one-fourth to one-third of their trees in the 2.5 to 30.5 cm (1 to 12.2 in) categories. Crabapples, also one of the top five most common species, had all the trees in the 2.5 to 30.5 cm (1 to 12.2 in) categories, but this is to be expected given the mature height of the cultivars in this species.

Wray and Prestemon (1983) defined full stocking as street tree populations having spacing between stems of approximately 15 m (49.5 ft), which was modified to 13.7 m (45.2 ft) for South Dakota because this is the common spacing in our communities. The communities included in this survey had a range of full stocking between 18.5% and 74.6% with an average of 45.6%, meaning slightly more than half of the planting sites are not occupied, particularly in the smaller communities (Table 1). This does not necessarily mean that planting all available sites would double the population of street trees; in fact, it would be less than double. It was common to find residents that had planted street trees closer than the typical spacing of 13.7 m (45.2 ft) and some properties had tree spacing less than 4.5 m (14.9 ft) along their portion of the street.

More information regarding heights, interference with power lines and sidewalks, and other characteristics for many of these communities and others are reported in Mason (2006).

## DISCUSSION

The primary reason for promoting street tree diversity is from a management, rather than an ecological, need. Diversity does not reduce the probability that a species will become infected or infested by an exotic stressor, but limiting the use of a species does reduce the potential for a stress to significantly affect management plans and budgets as a result of the loss of a host species. Much of the discussion of measuring diversity has been centered on species, typically a 10% limitation (Grey and Deneke 1986), but genera may be a more useful indicator when the concern is lethal stressors. Many of our exotic stressors are not limited to a species but to a genus. Dutch elm disease is not limited to American elm, although it is regarded as the most susceptible, but other North American species are affected as well as many European species (Sinclair and Lyon 2005). The emerald ash borer appears to successfully attack many North American ashes, although there is some variation in susceptibility (Hermes et al. 2005).

The threat posed at the genera level is possibly linked to the herbivore–plant relationship and geographic isolation of these relationships until recent time (Liebhold et al. 1995). The most common genera had their origin when the continents were connected by land bridges. Since that time, the close coevolution of stressors and hosts that occur in a forested region, often limiting the stressor to a secondary role, may work to the disadvantage of genera when the stressor is introduced into another forest region with the same genus present but with species that lack defenses (Gibbs and Wainhouse 1986). A community forestry goal of a 10% limit on a single species could give a false indication of stability if, for example, the street tree population was 10% green ash, 10% white ash, and 10% black ash, all susceptible hosts to the emerald ash borer.

This concern was addressed in a proposal by Santamour (1990) for a 10–20–30 limitation with no more than 10% of

**Table 2. Street tree characteristics by municipal league community population classes for the 34 surveyed communities.**

| Community class | Mean city population | n | Trees per capita mean ± SE | Planting sites per capita mean ± SE | Percent full stocking mean ± SE |
|---|---|---|---|---|---|
| Class 1 | 23,662 | 3 | 0.29 ± 0.14 | 0.41 ± 0.19 | 0.69 ± 0.01 |
| Class 2 | 1256 | 11 | 0.53 + 0.26 | 1.08 ± 0.42 | 0.49 ± 0.19 |
| Class 3 | 174 | 20 | 0.76 ± 0.57 | 1.65 ± 1.15 | 0.46 ± 0.15 |

SE = standard error.

**Table 3. Street tree population of 34 surveyed South Dakota communities by family, genus, and species.**

| Family | Percent of total | Genus | Percent of total | Species | Percent of total |
|---|---|---|---|---|---|
| Aceracae | 11.2 | *Acer* | 11.2 | *× freemanii* | 0.4 |
| | | | | *negundo* | 0.7 |
| | | | | *platanoides* | 2.3 |
| | | | | *rubrum* | 0.2 |
| | | | | *saccharinum* | 5.8 |
| | | | | *saccharum* | 1.5 |
| | | | | *tataricum* | 0.3 |
| Betulaceae | 0.1 | *Betula* | <0.1 | *nigra* | <0.1 |
| | | | | *papyrifera* | <0.1 |
| | | | | *pendula* | <0.1 |
| | | *Ostrya* | <0.1 | *virginiana* | <0.1 |
| Bignoniaceae | 0.2 | *Catalpa* | 0.2 | *speciosa* | 0.2 |
| Cupressaceae | 0.1 | *Juniperus* | 0.1 | *scopulorum* | <0.1 |
| | | | | *virginiana* | <0.1 |
| Elaeagnaceae | 0.2 | *Elaeagnus* | 0.2 | *angustifolia* | 0.2 |
| Fabaceae | 6.0 | *Gleditsia* | 5.3 | *triacanthos* | 5.3 |
| | | *Gymnocladus* | 0.2 | *dioicus* | 0.2 |
| | | *Robinia* | 0.4 | *pseudoacacia* | 0.4 |
| Fagaceae | 1.1 | *Quercus* | 1.1 | *macrocarpa* | 1.1 |
| | | | | *rubra* | <0.1 |
| Gingoaceae | <0.1 | *Ginkgo* | <0.1 | *biloba* | <0.1 |
| Hippocastanaceae | 0.2 | *Aesculus* | 0.2 | *glabra* | 0.2 |
| Juglandaceae | 2.2 | *Juglans* | 2.2 | *nigra* | 2.2 |
| Moraceae | 0.1 | *Morus* | 0.1 | *alba* | 0.1 |
| Oleaceae | 36.5 | *Fraxinus* | 36.3 | *americana* | 0.4 |
| | | | | *manushurica* (hybrids) | <0.1 |
| | | | | *nigra* | 0.5 |
| | | | | *pennsylvanica* | 35.3 |
| | | *Syringa* | 0.2 | *reticulata* | 0.2 |
| Pinaceae | 4.0 | *Larix* | <0.1 | *decidua* | <0.1 |
| | | *Picea* | 2.9 | *abies* | <0.1 |
| | | | | *glauca* | 0.9 |
| | | | | *pungens* | 2.0 |
| | | *Pinus* | 1.1 | *nigra* | 0.3 |
| | | | | *ponderosa* | 0.7 |
| | | | | *strobus* | <0.1 |
| | | | | *sylvestris* | <0.1 |
| | | *Pseudotsuga* | <0.1 | *menziesii* | <0.1 |
| Plataceae | <0.1 | *Platanus* | <0.1 | *occidentalis* | <0.1 |
| Rhamnaceae | <0.1 | *Rhamnus* | <0.1 | *cathartica* | <0.1 |
| Roseaceae | 9.0 | *Crataegus* | 0.1 | spp. | 0.1 |
| | | *Malus* | 7.7 | spp. | 7.7 |
| | | *Prunus* | 0.5 | *maackia* | 0.1 |
| | | | | *mandshurica* | <0.1 |
| | | | | *nigra* | <0.1 |
| | | | | *virginiana* | 0.3 |
| | | *Pyrus* | <0.1 | *communis* | <0.1 |
| | | | | *ussuriensis* | <0.1 |
| | | *Sorbus* | 0.7 | *aucuparia* | 0.7 |
| Salicaceae | 3.5 | *Populus* | 3.2 | *alba* | 0.6 |
| | | | | *balsamifera* | <0.1 |
| | | | | *deltoides* | 2.3 |
| | | | | *nigra* | <0.1 |
| | | | | *tremuloides* | 0.2 |
| | | *Salix* | 0.3 | *alba* | 0.3 |

(*continued*)

**Table 3. Street tree population of 34 surveyed South Dakota communities by family, genus, and species. (*continued*)**

| Family | Percent of total | Genus | Percent of total | Species | Percent of total |
|---|---|---|---|---|---|
| Simaroubaceae | <0.1 | *Ailanthus* | <0.1 | *altissima* | <0.1 |
| Tiliaceae | 5.6 | *Tilia* | 5.6 | *americana* | 2.8 |
| | | | | *cordata* | 2.8 |
| | | | | *mongolica* | <0.1 |
| Ulmaceae | 19.0 | *Celtis* | 5.3 | *occidentalis* | 5.3 |
| | | *Ulmus* | 13.7 | *americana* | 9.1 |
| | | | | *pumila* | 4.6 |

the street trees in a community in any one species, 20% in any one genus, and 30% in any one family. However, serious stressors that cross genera are relatively rare and those that cross families even less so. Gypsy moth (*Lymantria dispar*) does attack trees across a wide range of genera and families (Johnson and Lyon 1988) as well as Verticillium wilt (*Verticillium dahliae* and *V. albo-atrum*) and fireblight (*Erwinia amylovora*), two common urban pathogens (Sinclair and Lyon 2005). These are not commonly regarded as serious lethal stressors for street trees. There is probably little concern about the diversity of families used as street trees but not enough concern on the reliance on a limited number of genera.

Because the primary function of limitation is to reduce the probability of a significant disruption of management, a 10% limitation on genera may be our best measure of stability. This is a reasonable threshold based on the impact a stressor will have on a community. As an example, a community of 16,000 in South Dakota may have ≈12,000 street tree sites at full stocking. If a single genus comprising 20% of full stocking, 2400 trees, and has an annual loss of 6% to 10% of the genus as a result of a lethal stressor or 140 to 240 trees, not an unrealistically high loss rate based on what has occurred with emerald ash borer (Witter and Storer 2004) or Dutch elm disease (Wallner and Hart 1971), this removal effort would require ≈2 months for a crew at an estimated cost in South Dakota of $40,000 to $60,000. Because a community of this size may have an annual forestry budget of $200,000 to $250,000 and a single four-person forestry crew, the impact on the city budget and resources would be significant. This expenditure may be too high to be absorbed by the city, and it is likely that state and federal resources would be required. The same scenario would most likely be occurring in surrounding cities at the same time; thus, it is in the state's best interest to have inventory data.

Note that this 10% rule is not 10% of the trees planted, but 10% of full stocking. The use of full stocking as the measure allows for more consistent comparison and keeps the focus on limitation rather than strictly diversity. For example, if a community has 10,000 street tree sites of which only 60% are planted, the 10% rule would mean that no more than 1000 trees, not 600 trees, should be of any one genus. This use of a constant base prevents merely adding more trees of different species as appearing to increase stability. In this example of the community with 10,000 street tree sites, if 1500 were filled with ash and the other 4500 with other species, adding 2000 new trees, other than ash, could lead to the assumption that now the ash population has been reduced from 25% to 19% when, in fact, the same number of ash trees are present in the street tree population and there is no change in the hazard represented by the 15% of the full stocking in this genus.

South Dakota communities fall short of full stocking as do other communities across the country. One survey of 22 communities found stocking ranged from 12.6% to 70.3% with an average of ≈38% (McPherson and Rowntree 1989). Another study of five communities found street tree stocking ranged from 8.9% to 66.3% (McPherson et al. 2005).

McPherson and Rowntree (1989) categorized community street tree populations as strong dominance, codominance,

**Table 4. The five most abundant tree species in the 34 surveyed communities by percentage for the three municipal league community population classes.**

| Class 1 ($n = 3$) | | Class 2 ($n = 11$) | | Class 3 ($n = 20$) | |
|---|---|---|---|---|---|
| Species | Mean ± SE | Species | Mean ± SE | Species | Mean ± SE |
| Green ash | 32.0 ± 7.1 | Green ash | 40.8 ± 14.5 | Green ash | 42.3 ± 6.4 |
| Crabapple | 11.4 ± 6.6 | Silver maple | 9.3 ± 4.4 | Siberian elm | 9.8 ± 5.1 |
| American elm | 9.7 ± 3.6 | American elm | 8.1 ± 8.0 | American elm | 8.1 ± 1.8 |
| Hackberry | 6.2 ± 2.9 | Siberian elm | 7.3 ± 7.1 | Cottonwood | 6.1 ± 2.2 |
| Silver maple | 4.3 ± 0.4 | Hackberry | 4.1 ± 2.3 | Blue spruce | 5.0 ± 1.3 |

SE = standard error.

**Table 5. Diameter distribution of the five most abundant tree species in the 34 surveyed communities by percentage within a species.[z]**

| | 2.5–7.6 | 10.115.2 | 17.8–30.5 | 33.0–45.7 | 48.2–61.0 | 63.5–76.2 | 78.7–91.4 | 94.0–106.7 | 109.2 + cm |
|---|---|---|---|---|---|---|---|---|---|
| Species | 1–3 | 4–6 | 7–12 | 13–18 | 19–24 | 25–30 | 31–36 | 37–42 | 43 + in |
| *Acer saccharinum* | 5.4 | 5.4 | 16.0 | 10.8 | 26.0 | 23.5 | 5.9 | 2.8 | 4.2 |
| *Celtis occidentalis* | 6.7 | 3.5 | 26.8 | 35.9 | 20.6 | 1.6 | 3.9 | 0.0 | 1.0 |
| *Fraxinus pennsylvanica* | 10.1 | 11.8 | 26.8 | 28.6 | 18.8 | 7.1 | 0.7 | 0.1 | <0.1 |
| *Malus* spp. | 23.7 | 76.2 | 0.1 | — | — | — | — | — | — |
| *Ulmus americana* | 0.7 | 1.4 | 3.5 | 11.4 | 25.4 | 25.5 | 19.9 | 6.9 | 5.2 |

[z]Diameter measured at 1.37 m (4.5 ft).

and weak dominance based on the relative importance of a species, a measure of its relative abundance and basal area compared with other species within that community. Strong dominance populations were those in which one species' relative importance was greater than 25% and no other species was more than 15%. Codominance was where two species each have a relative importance greater than 10% and together their combined importance exceeded 25% and weak dominance was where no species relative importance was more than 10%.

A measure of relative importance may be unnecessary if the need is only to determine the hazard of an exotic stressor affecting the street trees. The abundance of a species is the critical factor for determining hazard, not necessarily basal area nor its relative abundance or basal area for a particular community. Our survey of communities in South Dakota found that only 9.6% of the street tree population is composed of small tree species such as crabapples; thus, a manager can assume that a threat by a lethal stressor will most likely be impacting tree species that are capable of reaching heights greater than 9.1 m (30 ft), and their removal will involve consider resources and their loss a significant impact to the appearance of the streets they shade.

Regardless of whether species abundance is linked to basal area, the concept of defining tree populations into categories related to hazards can be useful for communities to guide their future planting. If genera were substituted as the key measure rather than species, community street tree populations could be categorized based on the hazard any lethal stressor may have on the stability of their street tree population. Communities that have no genera comprising more than 10% of their population could be referred to as high stability. A low stability street tree population would be one where at least two genera each comprise more than 10% of the forest or a single genus comprising more than 25%. A medium stability community forest would have a single genus comprising more than 10% but less than 25%. This is based on the genera percentage of full stocking.

If abundance is based on full stocking, the most common genera in surveyed South Dakota community street trees is still ash with an average stocking percentage of 19.1% for the 34 surveyed communities followed by elm and maples, the other two genera that comprised more than 10% of the total street tree population (Table 6). Based on the categories of low, medium, or high stability, South Dakota has 17 of the surveyed communities in the low stability category, another seven in the medium, and 10 in the high stability category. Eight of the low stability communities are in this category based on the high numbers of ash, more than 25% of full stocking, another six based on ash and elm each being more than 10% of full stocking, two based on ash and maple each being more than 10% of full stocking, and one based on ash and crabapple each being more than 10% of full stocking. The seven medium stability communities are either the result of ash being more than 10% full stocking, four communities, or elm being more than 10% full stocking. Eight of the 10 high stability communities are class 3 communities and a relatively low number of trees are involved. The three surveyed class 1 communities have two in the low stability category as a result of high ash populations and the third is in the medium stability category attributable again to the number of ash. It appears that South Dakota communities are particularly vulnerable to emerald ash borer and, considering the current age of the ash population, will be vulnerable for the foreseeable future regardless of efforts made to increase diversity.

Although it is important for communities to begin limiting their use of genera, Richards (1993) discusses factors that may temper communities from reaching the 10% goal. First, a species, or genera, is only overused if other species or genera are better suited to the site. There may be environmental conditions that prevent a broad use of trees for a

**Table 6. The three most common genera found in 34 South Dakota surveyed communities as a percentage of full stocking.**

| Genera | Mean % ± SE |
|---|---|
| *Acer* | 4.3 ± 1.4 |
| *Fraxinus* | 19.1 ± 4.9 |
| *Ulmus* | 8.1 ± 3.2 |

SE = standard error.

particular location. Equally important is the need to select proven trees for large-scale planting within a community. Using tree species or genera that are poorly adapted, while creating short-term diversity, will not contribute to long-term stability. However, even in the harsh sites that occur in South Dakota, there appears to be enough choices for expanding the use of other genera such as corktrees (*Phellodendron* spp.) that can be found thriving in residents' lawns but is rarely used as a street tree in the state.

As Bassuk (1990) pointed out, although only a few species make up the majority of street trees, there is also a large number of species, often more than 50, that comprise the entire street tree populations. Some of these may be minor species as a result of objectionable fruit or other attributes; others may be site-sensitive and only able to thrive on a few select sites. Even given this as a consideration, the diversity of species and genera could be expanded in many communities. Gerhold et al. (1993) identified as potential street trees more than 70 species representing 37 genera and 19 families, although the adaptability of each would need to be checked for adaptation to the local conditions. A 10% rule for genera would still provide a sufficient plant palette for even a harsh climate such occurs on the Northern Plains. McPherson et al. (2003) identifies 92 species in 21 different genera as deciduous trees suitable for planting in zone 4, although some would be very marginal considering the spring and autumn extreme temperature fluctuations on the Northern Plains and not all the species listed are acceptable street trees.

## CONCLUSIONS

Although many of the surveyed communities have significant available planting sites along their streets, merely planting genera other than ash will not provide stability because the present number is sufficiently great enough that the cost of removal of these trees during an emerald ash borer epidemic will be a major disruption to these cities. Because ash represents a large proportion of the younger growing stock, the hazard will remain high for many decades or until the arrival of the insect into the state.

Planting the available planting sites with a more diverse selection of genera, if adapted to the sites, will provide long-term stability as the ash population matures and is replaced. The present high hazard, a level that will be maintained for the foreseeable future, clearly points to the benefit of monitoring and possible regulatory efforts at restricting the movement of ash firewood and logs into the state. The cost of removing these trees, even over an extended period, would have a major impact on the budgets of the state and communities and divert resources that could be used for other services.

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**Résumé.** Les agents de stress exotiques, tel l'agrile du frêne, sont une source d'inquiétude accrue pour plusieurs communautés en Amérique du Nord. Un des moyens pour évaluer le degré de risques que ces agents de stress peuvent représenter pour les arbres sous gestion publique d'une communauté est via un inventaire de leur arbres de rues. La *Division de la conservation de la ressource et de la foresterie du Dakota du Sud* a mené un inventaire des arbres de rues au sein communautés choisies de l'état et, à partir des données, a classé les communautés selon des catégories de stabilité en se basant sur le pourcentage de présence que représente chaque genre au sein de la population d'arbres de rues. La majorité des communautés étudiées se retrouvent dans la catégorie à faible stabilité en raison de la dominance du frêne de Pennsylvanie dans leur population d'arbres de rues.

**Zusammenfassung.** Exotische Schadinsekten wie der Eschenbohrer sind in vielen Gemeinden in Nordamerika eine wachsende Plage. Eine Form der Untersuchung dieser Gefahren, die diese Schadinsekten für die öffentlichen Bäume bedeutet, ist eine Inventur der Straßenbäume. Die Division Für Resourcenerhaltung und Forsten in Süd-Dakota führte bundesweit in ausgewählten Gemeinden Straßenbaum-Kataster durch und anhand dieser Daten wurden die Gemeinden in Kategorien eingeordnet, basierend auf dem Prozentsatz von voller Bestockung, die jede Gattung innerhalb der Straßenbaumpopulation repräsentiert. Die Mehrzahl der erhobenen Gemeinden sind in der Kategorie mit niedriger Stabilität wegen der Dominanz von Grüner Esche in ihren Straßenbaumpopulationen.

**Resumen.** Los insectos exóticos causantes de estrés, tales como el barrenador esmeralda del fresno, son una preocupación en incremento en muchas comunidades a través de Norte América. Un medio de evaluar el daño de esta plaga que se puede representar como publicidad a la comunidad para el manejo de los árboles es a través de un inventario de sus árboles urbanos. La División de Conservación de Recursos y Bosques de South Dakota condujo inventarios de árboles urbanos en comunidades seleccionadas a través del estado y, de estos datos, han localizado comunidades en categorías de estabilidad basadas en porcentaje del inventario que cada género representa dentro de la población de árboles urbanos. La mayoría de comunidades encuestadas están en la categoría de baja estabilidad debido a la dominancia del fresno verde en sus poblaciones de árboles.