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An Evaluation of Bur Oak (*Quercus macrocarpa*) Decline in the Urban Forest of Winnipeg, Manitoba, Canada

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Abstract. Winnipeg, Manitoba, Canada, has a large, indigenous population of bur oak (*Quercus macrocarpa* Michx.). In the 1980s, many of these trees were showing signs of decline, a disease caused by a complex of abiotic and secondary biotic stressing agents. Potential causal factors were investigated by comparing various aspects of 120 bur oaks visually rated as healthy or declined based on crown dieback levels. The results indicated that many selected bur oak trees predated surrounding urban development and that declined trees were significantly older with more severe stem wounds and competition from surrounding trees than healthy specimens. Average annual growth ring widths of healthy and declined trees were similar in the early part of the 20th century. However, decline actually began decades before symptoms were noticed, coinciding with a period of intense city-wide urban development, as growth of declined trees was slower than that of healthy trees beginning sporadically in the 1940s and consistently from 1974 to 2001. During the early years of decline, the year-by-year separation in ring width between the two categories was significantly positively related to precipitation levels. This suggested that in wet years, declined trees may have been surrounded by unfavorable water-logged soils, possibly as a result of natural drainage patterns being impeded by urban development.

Key Words. Dendrochronology; tree decline; urban development.

Bur oak (*Quercus macrocarpa* Michx.) is a large, slow-growing, deciduous tree native to North America (Johnson 1990). Winnipeg, Manitoba (49°53′N 97°09′W) is located at the northwestern boundary of the native range of bur oak and is the only major city in western Canada to have a large, indigenous population of mature oaks in its urban forest. Many of these trees are located in the city's parks and boulevards as well as on commercial and residential properties. The present oak forest in Winnipeg has regenerated after intensive logging in the region during the early and mid-19th century (Ross 1856; Dafoe 1998; St. George and Nielsen 2002). Together with several other native tree species, the bur oak in Winnipeg's urban forest provides functional, aesthetic, and economic benefits such as shelter, shade, beautification, and increased property values that improve the urban environment.

In 1986, city foresters reported that many of Winnipeg's bur oaks were showing signs of distress (Allen and Kuta 1994). Symptoms reported included crown dieback, epicormic shoot growth, and susceptibility to the two-lined chestnut borer (*Agrilus bilineatus*), a wood-boring beetle not known to attack healthy oaks. A preliminary investigation indicated that these symptoms were not caused by a single, aggressive primary pathogen, but instead were the result of a disease known as oak decline (Allen and Kuta 1994). In response to this problem, over 1700 affected bur oaks were removed from the city between 1986 and 2000 (M. Allen, pers. comm.). More recently, similar stress symptoms have been reported in other species of oaks in urban parks in Toronto and Oakville, Ontario (Ric and Bykov 2002; Hashemi 2004).

Tree decline can be defined as a premature, progressive loss of vigor not explained by an aggressive disease or insect, and has been observed to affect many tree species around the world (Ciesla and Donaubauer 1994). It is a complex disease involving environmental, tree, and pest factors (Houston 1974; Wargo 1996) and may be a natural ecologic response in trees growing in unsuitable conditions (Manion 1981). Manion (1981) created a widely accepted model for tree decline by classifying damaging elements into three groups: predisposing, inciting, and contributing factors. Predisposing factors are long-term, chronic, or slow-changing environmental factors, including climate, air pollution, site conditions such as soil compaction or fertility, and tree characteristics such as genetic potential and age that weaken plants growing in suboptimum sites (Manion 1981). Inciting factors are those that are more acute or short-term in duration such as defoliation, drought, frost, and mechanical injury. These events often cause drastic injuries and trigger further weakness and vulnerability in trees. Trees may attempt recovery after inciting factors have occurred but are often prevented by the weakening effects of predisposing stresses (Manion 1981). The recovery effort depletes the tree's energy reserves and compromises its defense systems, creating vulnerability to agents known as the contributing factors that ultimately may cause more damage than the inciting factors (Sinclair and Hudler 1988). Contributing factors are conspicuous, biotic, and often the final cause of death. However, they are frequently falsely blamed as being solely responsible for tree death instead of indicators of more prolonged stresses (Manion 1981). Wood-boring beetles, canker fungi, and root-decay fungi are all examples of contributing factors. The combined effects of sequential predisposing, inciting, and contributing factors can be described as a conceptual downward "spiral" of interactions leading to tree death (Manion 1981).

The two-lined chestnut borer—and, to a lesser extent, *Armillaria* root rot fungi—are well established as the most important contributing factors involved with oak decline in North America (Dunbar and Stephens 1975; Wargo 1977; Haack and Benjamin 1982). Because these pathogens are only harmful if oaks are weakened before infection, the overall objective of this study is to determine predisposing and inciting factors responsible for bur oak decline in Winnipeg. This was accomplished by comparing characteristics of healthy and declined bur oaks, including present-day tree and site conditions, and dendrochronologic evidence in relation to urban development and climate data.

MATERIALS AND METHODS

Area of Study

Winnipeg, Manitoba, Canada, is a city with an area of 465 km^2 (186 mi^2) and a population of roughly 620,000 residents (Statistics Canada 2004) found at the junction of the Red and Assiniboine rivers on the Canadian prairies. Urban development began in the 1860s near the present-day center of the city and expanded rapidly in the 1870s (Dafoe 1998). Many of the city's neighborhoods were built in the 1940s as a response to a postwar housing shortage (Dafoe 1998). In 1945, Winnipeg contained approximately 50,000 dwellings, and by 1960, that number had more than doubled (City of Winnipeg 2004). Further suburban development continued at a rapid pace until ≈1980 when rapid construction moved beyond the city limits to surrounding municipalities.

As part of the Red River valley, Winnipeg's soil tends to be black heavy clay with high fertility and poor drainage. The natural vegetation before European settlement was a mix of forest near the waterways shifting to grassland further away as moisture became less available. The arrival of European immigrants meant that almost all trees were harvested for firewood and construction materials in the mid-1800s leaving a barren landscape (Ross 1856; Dafoe 1998; St. George and Nielsen 2002). As a result, many of Winnipeg's present-day trees germinated during the regenerative time period of the mid- to late 1800s when there was little competition for light or water from established, dominant specimens.

Tree Selection

Bur oak trees included in the study were randomly selected from an eligible pool within the city of Winnipeg in the summer of 2002 and visually classified according to their crown dieback levels as either healthy (<5% dieback) or declined (>25% crown dieback). Sample selection was restricted to those trees that (1) were located at least 100 m (330 ft) from roads where toxic deicing salts are applied in the winter, (2) were not near any obvious recent major disturbances, (3) did not have wounds affecting more than 25% of the trunk circumference, and (4) had a trunk diameter at breast height (dbh; measured at 1.4 m [4.5 ft] from the ground) of at least 15 cm (6 in). Selected bur oaks were located mainly in parks, private yards, boulevards, cemeteries, golf courses, and along riverbanks. In total, 120 trees (68 healthy, 52 declined) were selected.

Data Collection

To characterize the selected trees and their growing environments, measurements were made of the trees' dbh, distance to nearest visible human-caused disturbance (such as pavement, buildings, or a sewer system), and level of surrounding tree competition within a radius of the tree's height. Because foliar nutrient levels can be used to detect potential soil problems (Dyer and Mader 1986; Kozlowski et al. 1991), leaf samples were collected from all trees (50 leaves from the edge of the crown) and analyzed for nutrient contents. The severity of trunk wounding, presence or absence of a buttress (tapering at the base of the stem that may indicate that the soil grade has not been raised), and presence and abundance of urban space (concrete, gravel, buildings) within a radius of each tree's height were visually rated. A subsample of 22 trees was selected for soil sampling and analysis of soil variables, including texture, bulk density, and chemical properties.

Increment cores were collected at breast height from all 120 trees using a 5.5 mm (0.22 in) Hagloff tree corer (Hagloff Inc., Madison, MS). Cores were prepared according to standard methods (Stokes and Smiley 1996). Annual ring widths were measured using a Velmex, Inc. measuring system and crossdated using the COFECHA computer program. Age estimates derived from cores taken at breast height underestimate the true age of the tree by the number of years required to reach breast height. Under ideal nursery conditions, oaks require at least 5 to 6 years to reach breast height (Rick Durand, pers. comm.) and often longer in a forest understory environment where oak seedlings may grow very slowly and have recurring shoot dieback (Abrams 1996). Climate data used in this study were obtained from Environment Canada (2002) and collected at Winnipeg International Airport (49°55′N 97°14′W, elevation 239 m [789 ft]) from 1938 to 2002.

RESULTS

General Tree and Environmental Information

Variables were compared between the two groups using Student's t-test ($\alpha = 0.05$) for continuous variables or χ^2 analysis ($\alpha = 0.05$) for ordinal variables unless otherwise noted. The overall mean tree age and standard deviation for all trees, excluding hollow specimens for which age data were not available, was 102.3 ± 31.4 years (Table 1). Healthy trees were significantly younger than declined trees (94.6 ± 30.9 and 112.1 ± 29.4 years, respectively), although there were no differences in dbh between the two groups (data not shown).

A comparison of wound ratings for the 120 trees showed there was a significant difference in the proportions of trees with different wound ratings between the health categories (Table 1). The healthy category was dominated by trees rated as having 5% to 10% of their trunk circumference affected by wounding and relatively few with 10% to 25% of damaged trunk circumference. The distribution in the declined category was significantly different with a smaller proportion of trees rated as slightly wounded (5% to 10% wounding) and a higher number with the most severely wounded rating. In short, the declined category had a higher percentage of trees in the extreme wound categories than the healthy category.

Declined trees had significantly more competition from surrounding trees than healthy trees (Table 1). Bur oak was by far the most abundant competing tree species surrounding sample trees, accounting for over 50% of average total competition, and appeared to account for most of the differences in total competition between the health categories. Bur oak was followed in order of decreasing abundance by elm, ash, maple, basswood, poplar, and spruce species, although none of these other species differed in abundance between the health categories (data not shown).

Many variables recorded were not significantly different between the two health categories. These included the presence or absence of tree buttresses (a total of 66% of the 120 sample trees had visible buttresses) and all foliar nutrients measured when considered both separately in Student's t-test and together in multiple discriminant analysis (percentages of N, P, K, S, Mg, Ca, and Na; data not shown).

Overall, 46% of the 120 sample trees had space characteristic of urban areas (concrete, covered soil, unavailable soil space from building basements) within a radius of the tree's height, but there was no significant difference between the categories. Analysis of soil variables also revealed no significant difference between soil collected around the subsamples of healthy and declined trees for bulk density, percent organic matter, electrical conductivity (EC), pH, and percentages of sand, silt, and clay. The only soil variable that varied significantly was total exchangeable cations, which was higher in soil surrounding healthy trees. Of the extractable soil ions—NO_3^-, $PO4^{3-}$, K^+, $SO4^{2-}$, Ca^{2+}, Mg^{2+}, and Na^+—the only significant difference between trees in the two health classes investigated was that Mg^{2+} was higher around healthy trees than declined trees (data not shown). Levels of all ions were highly variable among sites, especially Na^+.

Tree Ring Data

Ring width series for individual trees were not processed to remove age- or size-related trends, because this could have masked the decline signal in the series. However, because tree age is known to directly influence annual growth ring widths (Fritts 1976), trees with no rings before 1930 were excluded from this comparison so that the average ages of both groups of remaining trees (healthy $n = 47$, declined $n = 48$) were not significantly different. Average ring widths for all years together and each individual year were compared between the healthy and declined groups using Student's t-tests ($\alpha = 0.05$). Only values from the years 1900 to 2001 were included to ensure sample sizes for each year were reasonably large.

Table 1. A comparison of various potential decline indicator variables for 120 bur oak trees in Winnipeg, Manitoba, Canada, visually rated as healthy (*n* = 68) or declined (*n* = 52) based on crown dieback levels[z].

	Tree type		
Decline indicator	Healthy	Declined	Total
Age (years since breast height)[y]	94.6 ± 30.9 a	112.1 ± 29.4 b	102.3 ± 31.4
Wounding (visual rating based on trunk circumference wounding)[x]	0 = 32%, 1 = 53%, 2 = 15% a	0 = 44%, 1 = 31%, 2 = 25% b	0 = 38%, 1 = 43%, 2 = 19%
Total tree competition (cm^2 competing tree trunk basal area/m^2 growing area)	19.2 ± 12.2 a	27.4 ± 14.7 b	22.7 ± 13.9
Total competition from oaks (cm^2 competing tree trunk basal area/m^2 growing area)	9.9 ± 9.9 a	19.8 ± 15.6 b	14.2 ± 13.6

[z]Values for variables with no letters in common were statistically different ($P < 0.05$), according to Student's t-test, unless otherwise noted.
[y]Sample numbers lower as a result of several hollow trees: healthy $n = 63$, declined $n = 49$.
[x]Comparison made with χ^2 analysis test of independence. Visual wound ratings correspond to the percentage of the trunk circumference visibly affected by wounds or scars: 0 = <5%, 1 = 5–10%, 2 = 10–25%.

The overall comparison revealed that ring widths of healthy trees were generally wider than those of declined trees (1.668 ± 0.760 mm [0.0657 ± 0.0299 in] and 1.319 ± 0.707 mm [0.0519 ± 0.0278 in], respectively). The yearly comparisons were more revealing, demonstrating that the radial growth patterns in the two categories were very similar from 1900 to the early 1940s (Figure 1). In the mid-1940s, when the trees were an average of 57 years of age, declined trees began a statistically significant progressive decrease in ring width relative to the healthy category. The statistical differences were sporadic until 1974, when ring widths in the declined category began to be consistently smaller until 2001, the last year of measurable ring widths at the time of study. Despite the divergent long-term trends between the two groups, year-to-year changes in their ring widths continued to covary. Note that the apparent differences in growth between the two categories from 1900 to 1915 were not significantly different at $P < 0.05$, likely a result of smaller sample sizes during that time period.

St. George and Nielsen (2002) demonstrated that bur oak ring width in southern Manitoba was strongly correlated with annual precipitation in Winnipeg. In this study, regressions were performed between annual ring growth and precipitation levels from many combinations of months, including those from the corresponding current growing year, and the previous growing season. Regressions performed between mean annual ring widths for healthy trees and monthly precipitation data from 1938 to 2001 (the period in which data were available) indicated that precipitation was significantly related to variability in annual mean ring widths during that time period ($P < 0.05$). The combined levels of May, June, and July precipitations in the current growing year had a small but significant positive R^2 value of 0.147 ($P < 0.05$), whereas total January through September levels of the current growing year had a positive R^2 value of 0.142 in terms of variation in average annual ring widths of healthy trees ($P < 0.05$).

Based on the observed divergence of ring widths between the healthy and declined trees, we isolated a "critical period" in terms of tree decline: the period beginning when average annual ring widths of healthy and declined trees were first statistically different and ending when the two groups became consistently different (1944 to 1974). This period is highlighted because it may have been the time when predisposing and inciting factors caused short-term growth differences between the groups but before contributing factors became established and began to damage now-declined trees. During this interval, the differences between mean ring width for the healthy and declined trees were positively correlated with

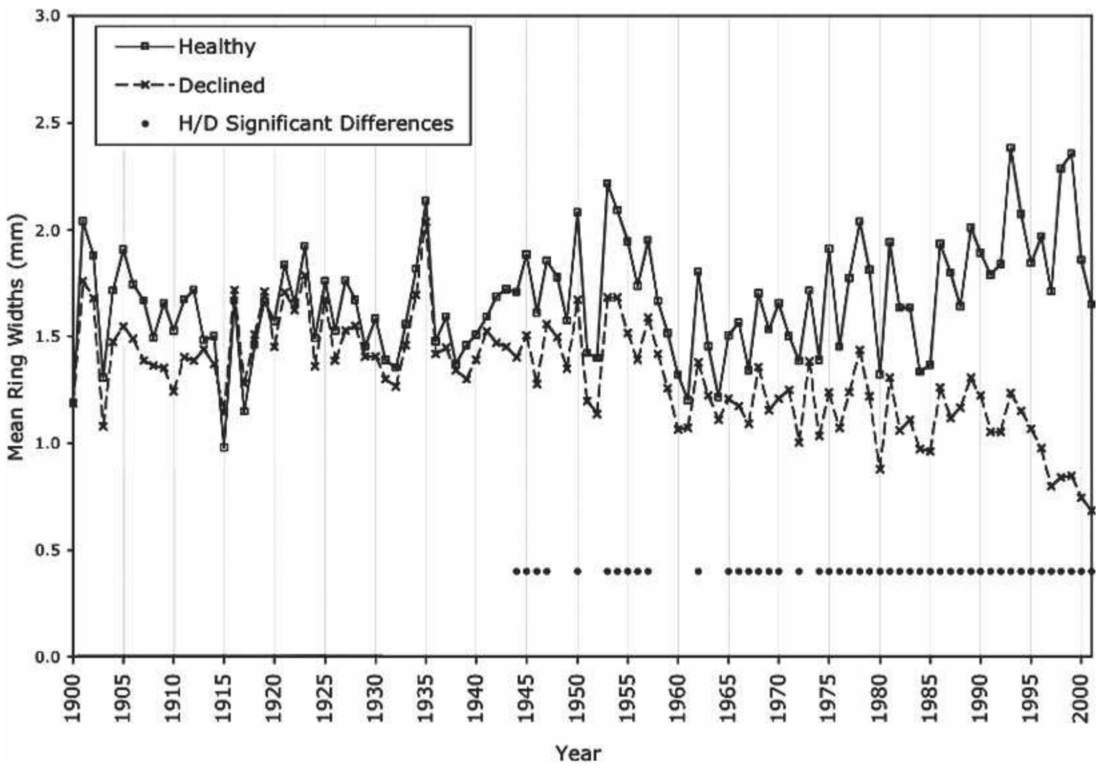

Figure 1. Mean annual tree ring widths for 47 healthy (H) and 48 declined (D) bur oak trees of similar ages (113.7 ± 25.6 years) in Winnipeg, Manitoba, from 1900 to 2001. Circles signify years when ring widths were significantly different between the two categories (*P* < 0.05).

precipitation (Figure 2). Regression analysis indicated that the combined precipitation levels from January to September of the current growing year had the strongest relationship with the difference in annual ring widths between the groups out of all the combinations of months tested. January to September precipitation levels explained 41.4% ($P < 0.05$) of the variation in difference between ring widths of healthy and declined trees during the critical period (Figure 2).

DISCUSSION

The results from this study revealed that, similar to many other documented cases of tree decline, bur oak decline in Winnipeg is a complex problem that began decades before visible symptoms were reported. From the information obtained in this study, a region-specific version of a tree decline model developed by Manion (1981) was formulated, specifically in terms of identifying potential predisposing and inciting factors involved in bur oak decline in Winnipeg.

Observations of the city's historical developmental record (Dafoe 1998; City of Winnipeg 2004) and the tree ring data in this study confirm that the bur oak population in Winnipeg predated most urban development in the city, consistent with previous observations (Allen and Kuta 1994; St. George and Nielsen 2002). Declined sample trees were on average older than healthy trees, a finding similar to decline studies in other oak species conducted in the southern United States (Tainter et al. 1990; Oak et al. 1996) and Sweden (Sonesson 1999). A closer inspection of the data in this study revealed that there were approximately equal numbers of healthy and declined sample trees with high age values but very few declined trees with low age values. This difference suggests that increasing tree age may have been a predisposing factor in bur oak decline in Winnipeg, as suggested by Allen (2000), and is consistent with the general notion that trees may lose vigor with age (Manion 1981; Franklin et al. 1987).

Before the 1940s, healthy and now-declined trees had very similar growth patterns because they were presumably growing in relatively undisturbed natural habitats, where urban development was absent or not severe enough to influence tree growth. This did not support hypotheses made in other studies that now-declined trees may be more vigorous (Houston 1973; Jenkins and Pallardy 1995; Oak et al. 1996; Stan-

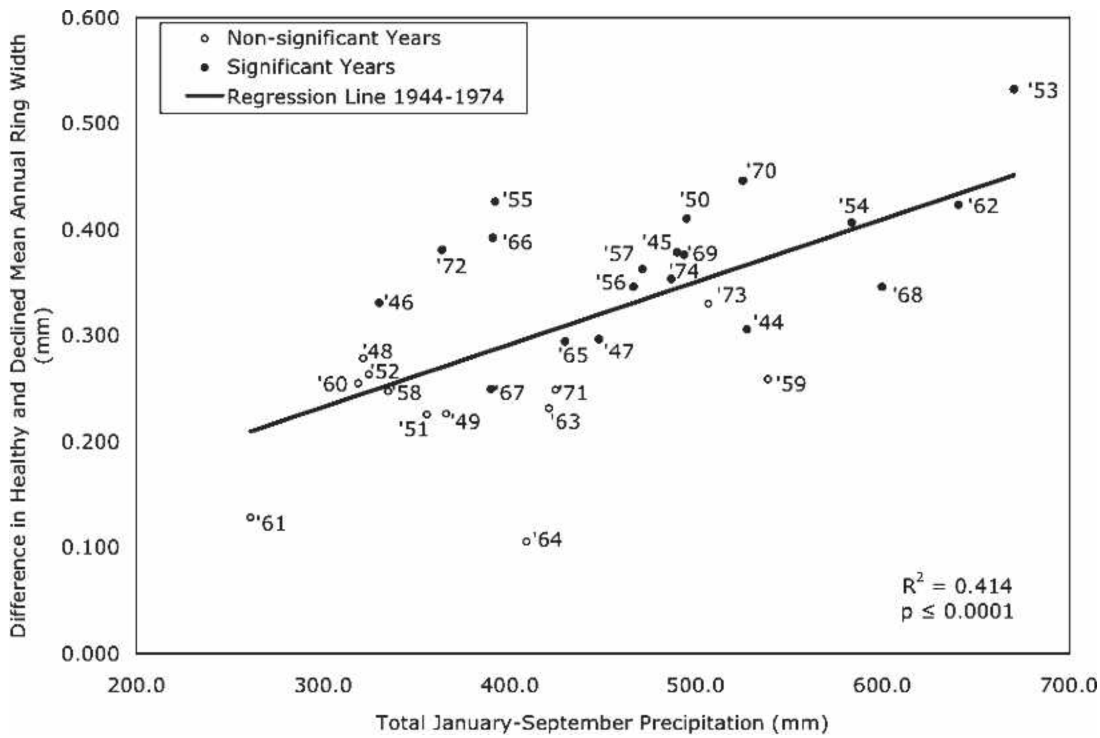

Figure 2. A regression of the difference in annual mean tree ring width between 47 healthy and 48 declined bur oak trees in Winnipeg, Manitoba, versus the combined precipitation levels from January to September of the current growing year in each year from 1944 to 1974. Circles are labeled by their corresponding years. Solid circles indicate years when rings from healthy trees were significantly larger than those from declined trees ($P < 0.05$), whereas hollow circles indicate years when the two categories were not significantly different. The ages of the trees in the two categories were not significantly different (average age of all 95 trees were 113.7 ± 25.6 years).

dovar and Somogyi 1998) or less vigorous (Amorini et al. 1996; LeBlanc 1998; Pedersen 1998) than healthy trees in the early parts of their lives and thus have different energy demands. Instead, the observation in the current study suggests that something about the now-declined trees or their environments may have changed to cause the decrease in growth. A comparable pattern of similar growth followed by divergent growth between visually classified healthy and declined oaks was observed in the southeastern United States (Tainter et al. 1990). The divergence was attributed to a series of short-term droughts, although it was not clear why certain trees became declined, whereas others remained healthy. Widespread symptoms of bur oak decline in Winnipeg were first noted in the 1980s (Allen and Kuta 1994); however, the observed ring width patterns indicate that the decline actually began in the 1940s, much earlier than estimated by preliminary investigations (Allen and Kuta 1994; Allen 2000). This finding is consistent with reports that a decrease in annual ring widths in declining trees is evident much sooner than the onset of visual symptoms (Kenk 1983; Hornbeck and Smith 1985; Greve et al. 1986) and that declining oaks grow slower than their healthy counterparts for decades before death (Jenkins and Pallardy 1995; Pedersen 1998).

The divergence in growth rate between healthy and declined trees corresponded with a period of intense urbanization in Winnipeg, where many neighborhoods were constructed in a short time in previously undeveloped areas to accommodate the demand for housing after World War II (Dafoe 1998). Urbanization may have positive (i.e., possibly from removal of competing trees) or negative (i.e., soil compaction, wounding) effects on bur oak growth (Catton 2005). It appears that overall, healthy oaks were unaffected or positively affected by surrounding development as demonstrated by their increased growth rate over time. This may be a result of healthy trees being younger than the declined trees at the time of urban disturbance, because established oaks are well known for their poor adaptability to the changes caused by urbanization (Ware 1970; Allen and Kuta 1994). In some cases, urban disturbances may have been beneficial around healthy trees as demonstrated by their lower levels of surrounding competing trees. In addition to having high levels of competition, some now-declined specimens may have been exposed to more severe or recent disturbances as indicated by the more severe trunk wounding observed in the declined group of trees.

A change in natural drainage patterns is often an unfortunate outcome of urban development, and oaks in formerly well-drained areas that are suddenly left in standing water from high precipitation levels suffer greatly from the lack of soil oxygen (Ware and Howe 1974), a known causal factor in the decline of oak (Gaertig et al. 2002) and other tree species (Dyer and Mader 1986). In this study, the association of wet years with poor growth of now-declined trees, but not healthy trees during the critical period, suggests the possibility that trees in the two categories were being exposed to different levels and/or durations of soil moisture, presumably a combination of high precipitation levels and impeded drainage around now-declined trees. Considering the low tolerance of bur oak to flooding (Johnson 1990), and the poor internal drainage of Winnipeg's heavy clay soils, this potential change would have been a major stress for now-declined sample trees. Mature bur oak trees have been observed as being able to survive up to 30 consecutive days of saturated soil during the growing season, compared with more flood tolerant species such as cottonwood (*Populus deltoides*) or white ash (*Fraxinus americana*) that can survive an entire growing season under deep flooding (Whitlow and Harris 1979). The damaging effects of urbanization to bur oaks may stretch far beyond immediate physical impacts at the site of development, particularly in naturally forested areas where no manmade drainage systems exist. This idea may be supported by the increased competition levels surrounding declined trees as opposed to healthy trees (Table 1), which may have been in more "street-like" environments with more immediate urban disturbance but better drainage. Impeded drainage was thought to be the main cause of a decline in a stand of bur oak in southern Manitoba near a newly constructed road (Boone 2003) and several stands of oak forests in Winnipeg with known drainage changes from recent development (Catton 2005). It should be noted that neither physical nor chemical soil variables nor leaf nutrient levels differed between healthy and declined trees in this study.

Contrary to many studies on oak decline (Tainter et al. 1990; Pedersen 1998), drought did not appear to be a major causal factor in the decline of the bur oaks in this study. Although declined trees were generally less vigorous than healthy trees during the critical period (Figure 1), the groups behaved most similarly in dry years, which may not be surprising considering that bur oak is known to be a relatively drought-tolerant species but vulnerable to flooding (Johnson 1990). However, the fact that now-declined bur oaks were less able to capitalize on their growing environments compared with healthy trees, even in years when poor soil aeration was presumably not a factor, supported the idea that now-declined trees likely suffered from root damage (McClenahen and Dochinger 1985; Innes 1990). Whether this damage was a direct (i.e., root severance) or indirect (i.e., changed drainage patterns) result of urbanization or other factors is not clear and probably varied with specific site conditions. Although drought was not shown to be a major inciting factor in bur oak decline in Winnipeg, it is not possible to dismiss its potential importance in individual cases depending on the severity of the stress and the health condition of the trees.

The present-day environmental data examined in this study generally did not support the notion that seemingly detrimental urban disturbances such as high amounts of concrete or building construction were directly involved in bur oak decline. In fact, according to the information collected on present-day site conditions, bur oaks can be declined in apparently favorable environments and remain healthy in conditions normally interpreted as stressful. This conclusion is generally counterintuitive and demonstrates the problems with trying to represent past disturbances by visually examining present conditions. Nevertheless, from the tree ring data and the development history of Winnipeg after World War II, it is reasonable to assume that urban disturbances may have been predisposing and inciting factors involved in early stages of bur oak decline in Winnipeg. It would be interesting to study lag times between known predisposing or inciting factors and tree response in terms of both ring width growth patterns and crown dieback.

SUMMARY

This study demonstrated that tree age, direct physical disturbances from urban development (i.e., wounding), and indirect disturbances such as impeded drainage patterns may be predisposing factors in bur oak decline in Winnipeg, whereas high precipitation levels may be an important inciting factor. Together these factors are likely the main reasons why some bur oaks in Winnipeg are affected by contributing factors in oak decline, in particular the two-lined chestnut borer.

Based on the proposed decline model emanating from this study, it is recommended that not only should care be taken directly around bur oaks before and during urban development, but that consideration should also be given to widespread effects on drainage patterns, particularly in undisturbed areas containing bur oaks. As well, because the incidence of decline increases with tree age, it is important to replenish the bur oak population by planting new individuals in urban landscapes, because young trees generally have more ability to adapt to stressful conditions than older specimens (Manion 1981).

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Résumé. Winnipeg au Manitoba (Canada) possède une importante population de chênes à gros fruits (*Quercus macrocarpa* Michx.). En 1980, plusieurs de ces arbres ont montré des signes de dépérissement, une maladie causée par un complexe d'agents stressants abiotiques et biotiques secondaires. Les facteurs potentiels en cause ont été étudiés en comparant divers aspects de 120 chênes à gros fruits visuellement qualifiés en bonne santé ou en dépérissement, et ce en se basant sur le degré de cime dépérissante. Les résultats ont indiqué que plusieurs des chênes à gros fruits sélectionnés dataient d'avant le développement urbain tout autour de ces derniers et aussi que les arbres dépérissants étaient significativement plus âgés avec plus de blessures sévères aux branches et qu'ils devaient subir plus de compétition des arbres qui les entouraient, et ce par rapport aux arbres en meilleure santé. Les largeurs des anneaux annuels de croissance des arbres en bonne santé et de ceux dépérissants étaient relativement similaires au début du 20^{e} siècle. Néanmoins, le dépérissement s'est amorcé des décennies avant que les premiers symptômes soient observés – ce qui coïncidait avec une période de développement urbain intense – alors que la croissance des arbres devenait plus faible que celle des arbres en bonne santé, et ce de manière sporadique dans les années '40 et de manière plus systématique de 1974 à 2001. Au cours des premières années du dépérissement, la distinction entre les deux catégories d'arbres en regard de l'épaisseur des anneaux de croissance était significativement corrélée avec les niveaux de précipitations durant l'année de croissance, ce qui laisse à penser que le drainage naturel ait pu être menacé par le développement créant ainsi des conditions non favorables de sol imprégné d'eau.

Resumen. Winnipeg, Manitoba, Canada tiene una gran población nativa de encinos (*Quercus macrocarpa* Michx.). En los 1980s, muchos de estos árboles mostraron signos de declinación, una enfermedad causada por un complejo de agentes de estrés abiótico y biótico. Los factores causales potenciales fueron investigados comparando varios aspectos de 120 encinos visualmente tasados como saludables o en declinación, con base en niveles de muerte descendente en la corona. Los resultados indicaron que muchos encinos seleccionados se encontraban en los alrededores de los desarrollos, y que los árboles en declinación fueron significativamente más viejos con heridas del tronco más severas y competencia de los árboles circundantes que los especimenes saludables. El crecimiento promedio anual con el ancho de los anillos de árboles saludables y en declinación fue similar en la parte temprana del siglo 20. Sin embargo, la declinación empezó décadas antes de que los síntomas fuesen notados, coincidiendo con un período de intenso desarrollo urbano de ampliación de la ciudad, a medida que el crecimiento de los árboles en declinación se hizo más lento que los de los árboles saludables empezando esporádicamente en los 1940s y consistentemente de 1974 a 2001. Durante los primeros años de declinación, la separación en amplios anillos de crecimiento entre dos categorías fue relacionada significativamente positiva a niveles de precipitación durante el año de crecimiento, sugiriendo que los patrones naturales de drenaje pudieron haber sido impedidos por el desarrollo, creando suelos saturados desfavorables.

Zusammenfassung. Die Stadt Winnipeg in Manitoba, Kanada, hat einen großen nativen Bestand an Quercus macrocarpa. In den 80ger Jahren zeigten viele dieser Bäume Absterbeerscheinungen, verursacht durch einen Komplex aus abiotischen und sekundären biotischen Stressfaktoren. Durch Vergleich von verschiedenen Aspekten wurde an 120 Eichen potentielle Krankheitsfaktoren untersucht und die Bäume dabei durch visuelle Ansprache als gesund oder absterbend eingestuft. Die Ergebnisse zeigten, dass viele der ausgewählten Eichen sich in der städtischen Umgebung selbst angesiedelt haben und viele der absterbenden Bäume älter, mit mehr Stammwunden und unter Konkurrenzdruck durch die Nachbarbäume standen. Die durchschnittlichen Jahreszuwachsringe der gesunden und kranken Bäume waren im frühen 20. Jahrhundert gleich. Dennoch begann das Absterben bereits Jahrzehnte vor dem ersten Auftreten der aktuellen Krankheitssymptome. Das war etwa zeitgleich mit der intensiven Stadtentwicklung, als der Zuwachs der befallenen Bäume plötzlich hinter die anderen zurückblieb, so beobachtet sporadisch in den 40ger Jahren und anhaltend von 1974 bis 2001. Während der ersten Jahre des Absterbens war die Weite der Jahresringe deutlich positiv korreliert mit dem Ablagerungslevel während der Wachstumsperiode, welche zeigten, dass natürliche Drainageverhältnisse durch Entwicklungsmaßnahmen verändert werden können, indem sie Böden mit Staunässe entstehen lassen.