4. Results & Analysis

This chapter provides a general summary of County trends based on the MNHS and LSWS field surveys and on spatial analysis of the woodland patches in Middlesex County.

4.1 WOODLAND PHYSIOGRAPHY

Table 4 is a comparison between the area of physiographic types in Middlesex County and the area covered by woodlands for each physiographic type. Although Undrumlinized Till Plains, Till Moraines and Clay Plains are common physiographic types in Middlesex County (Table 4), only a relatively small proportion of these areas are covered in woodlands. Remnant woodlands in these areas tend to be smaller and of uniform geometric shape, occurring as isolated fragments aligned with roads and located along lot boundaries at the rear of farm lots. The absence of relief makes Undrumlinized Till Plains relatively easy to farm. Till Moraine features are easy to farm in the areas where the ice flattened the landscape, but more difficult in areas where deposits of unsorted materials and deep scouring by the ice heavily dissected the landscape. Flat clay plains may be good or poor for agriculture, depending on the nature of the soil overlaying the relatively impermeable clay layer. In general, flat homogeneous areas have experienced the greatest loss of woodlands due to their high agricultural value.

Kame Moraines, Peat and Muck, Beveled Till Plains and Beaches or Shore Cliffs are uncommon physiographic types in Middlesex, yet a relatively large proportion of these areas are covered in woodlands (Table 4). Peat and Muck soils, which occur on valley bottoms, are too saturated to farm unless drained and are generally used for cash crops. Remnant wetlands tend to be irregularly shaped and account for a high proportion of the area in these bottom lands. Woodlands in riparian landscapes tend to be long and continuous, but irregularly shaped. The strong relief of Kame Moraines, Shore Cliffs and Beveled Till Plains are not easy to farm and therefore more of these areas are wooded. Sandy soils found in Sand Plains, Spillways and Kame Moraines are dominated by relatively large forest patches that are irregularly shaped and frequently linked to other patches. Sandy soils provide high groundwater recharge potential and good drainage to the subsurface. Undulating topography creates low-lying wet environments where the water table intersects the surface, contrasting with the well-drained hills. Poor drainage and undulating topography are not conducive to highly mechanized agricultural practices nor to agricultural crops with deeper or taproot systems (Buckman and Brady 1961).

Table 4. Comparison between the area of physiographic types in Middlesex County and the area covered by woodlands for each physiographic type.

PHYSIOGRAPHIC TYPE	AREA IN COUNTY (ha)	AREA OF PHYSIOGRAPHIC TYPE COVERED IN WOODLANDS (ha)	COMMENTS
Kame Moraine	284	37	- accounts for less than 3% of the area in Middlesex County - between 10%-15% of kame moraines are woodlands
Peat / Muck	569	67	- accounts for less than 3% of the area in Middlesex County - between 10%-15% of peatlands are woodlands
Beveled Till Plain	2276	312	- accounts for less than 3% of the area in Middlesex County - between 10%-15% of beveled till plains are woodlands
Beach	3414	492	- less than 3% of the area in Middlesex County - between 10%-15% of beaches are woodlands
Spillway	29584	5443	- accounts for 10% of the area in Middlesex County - more than 20% of spillways are woodlands
Till Moraine	55186	5795	- accounts for 20% of the area in Middlesex County - between 10%-15% of till moraines are woodlands
Sand Plain	55755	10259	- accounts for 20% of the area in Middlesex County - approximately 20% of sand plains are woodlands
Clay Plain	59169	8402	- accounts for 20% of the area in Middlesex County - between 10%-15% of clay plains are woodlands
Unbeveled Till Plain	76521	6428	- accounts for more than 25% of the area in Middlesex County - less than 10% of unbeveled till plains are woodland

A breakdown of treed communities by dominant species is given in Appendix 7. Treed communities dominated by Red and Silver Maple occurred in all physiographic types. Treed communities dominated by Sugar Maple and Black Walnut occurred in all physiographic types except Peat, while Ash species (Red and Green) occurred in all physiographic types except Beach. White Elm occurred in all physiographic types except Kame Moraines. Other community dominants varied among the physiographic types.

4.2 LANDOWNER CONTACT

Of the 556 landowners that were contacted, 245 (44%) responded by returning their consent forms by mail or by phone call. Considering that there was no follow-up contact after the initial mailing, the positive response to our request to access properties was greater than anticipated. The rate of consent was 80% of the total returned forms or 35% of the total number of landowners that were contacted (*i.e.* 195 landowners granted permission for a field inventory of their property). Permission was obtained to inventory 96 woodlands in full or in part. However, time and budget restrictions meant that only 68 woodland patches were inventoried for MNHS.

The relative frequencies of physiographic types was the same for both the 200 patches selected for sampling and the 68 patches actually sampled in the field ($X^2_{0.05, 8} = 15.507$, $X^2_{obs} = 5.199$). When landowner permission was not obtained for all or most of a woodland patch, an alternate patch was substituted. The relative frequencies of physiographic types were the same for both the 200 patches selected for sampling and the patches where landowner permission was not obtained ($X^2_{0.05, 8} = 15.507$, $X^2_{obs} = 5.092$).

The positive response to our request to access properties was similar to that experienced in the Oxford County Terrestrial Ecosystems Study (UTRCA 1997, Vanderschot 1997). The amount of detail and information provided to the landowners may have had an overall positive impact on the consent rates. However, the landowner contact process could have been improved by:

- contacting landowners before spring when they were not as busy;
- explaining in detail how the property would be accessed and the amount of time that would be spent on each particular property; and
- following up the initial contact letter with a phone call if the landowner did not respond. This would have immediately clarified any misunderstandings that the landowner might have had about the study. This was not done in MNHS because the target number of woodland patches was met.

Landowner follow-up is an integral part of any successful landowner contact program. At the conclusion of the Middlesex Natural Heritage Study (MNHS), landowners that granted permission were provided with a follow-up package containing information specific to their woodland patch (Appendix 8). The package consisted of a thank-you letter, a natural heritage fact sheet reiterating the study's goals and summarizing the results, a detailed map of the landowner's woodland showing community boundaries and a description of the plants and animals found on the property during the field visit. It is anticipated that the information in the follow-up package will assist landowners in understanding the importance of their woodlands with respect to other woodlands in Middlesex County. Since long term landowner follow-up is key to developing and maintaining a positive relationship with landowners in Middlesex County, landowner contact will continue to be an important aspect of the Middlesex Natural Heritage Study as final reports are completed and newsletters, workshops and open houses are scheduled.

4.3 CHANGE IN FOREST COMPOSITION

Prior to European settlement in the early nineteenth century, much of southwestern Ontario was covered with relatively continuous tracts of closed canopy hardwood forest. From the mid 1800s to the mid 1900s, rapid colonization and conversion of forest to agricultural land fragmented this forest into small, isolated fragments. Since the mid-1900s, agricultural expansion has stabilized, and marginal lands have been left to regenerate back to a semi-natural state. A comparison of dominant tree species in the historic Conservation Authority reports produced from 1950 to the1960s with the species found in the field in 2001 for each of the 153 surveyed woodland patches in Middlesex County (Figure 7) can be used to identify changes in forest composition that have occurred over time.

The historic forest composition was predominantly Sugar Maple - American Beech. Silver Maple and White Elm occupied similar but poorly drained soils on higher land. The relative proportions of Silver and Red Maple, ash, aspen, hickory and Tamarack have all increased while White Elm, Black Cherry, oak and American Beech have decreased. The relative dominance of Sugar Maple, Yellow Birch and Basswood has remained the same. Forest management techniques, combined with the tolerance of tree species to shade, may be one explanation for this shift in species composition. Sugar Maple, considered to be a shade tolerant, climax tree in this region (Rowe 1972), was valued for its timber and for sugar production. It was both desirable and relatively easy to maintain this species. American Beech, on the other hand, is not considered a valuable timber tree and it may have been actively managed out for more favourable species. Aspen and ash species, generally

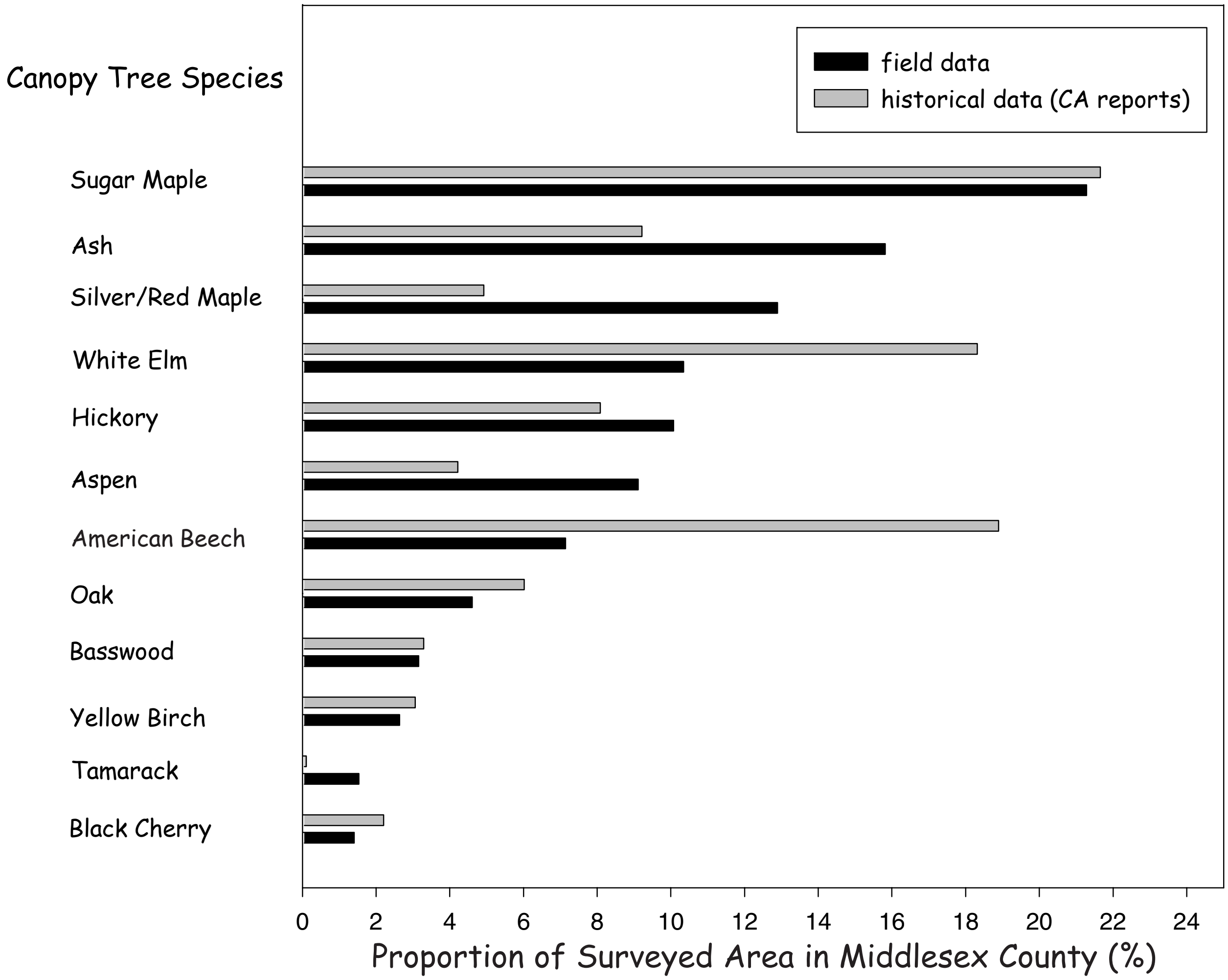


Figure 7. A comparison of the relative dominance of canopy tree species in the surveyed patches between the 1950s to 1960s and data collected in the field for MNHS and LSWS.

considered to be shade intolerant, early successional trees, have increased since the 1950-1960s reports. The increase in these species reflects the pioneer nature of many of the forests today. Black Cherry and oak, also shade intolerant species, have not increased since the 1950-1960s reports since they do not readily regenerate after being logged. Finally, the decrease in elm can be attributed to both recent pest outbreaks, such as Dutch Elm disease, and more than 40 years of over logging.

Other explanations for the changes in species composition between the 1950-1960s reports and the 2001 field survey could be changes in the farm industry, economic markets and drainage technology. Human expansion since the 1950s has caused additional clearing of forested land and draining of wetlands for recreational, logging and grazing activities, while recent changes in the farming industry have resulted in more lands near riparian areas being left to naturally regenerate. Large scale effects such as climate change may also be contributing to the shift in species composition.

4.4 FIELD SURVEY FINDINGS

4.4.1 Vascular Plants

Sedge (*Carex*) species were removed from the analysis since they were not identified in the MNHS. An assessment of the distributions for richness, mean conservative coefficient, wetness and weediness for the remaining vascular plants collected in the MNHS and LSWS showed similar measures of central tendency and dispersion between the two studies. Therefore, the data for MNHS and LSWS were combined to develop trends for the entire County.

<u>*Species Richness*</u>
The number of species recorded in each patch can be used as a measure of overall biological diversity and, therefore, woodland health. A total of 581 plant species were recorded in the MNHS and the LSWS, of which 438 were native (143 were non-native). The total number of native species represents approximately 5% of the native flora recorded for Southwestern Ontario and 37% of that recorded for Middlesex County. The number of native plant species recorded per patch ranged from 19 to 248. Sixty-three native

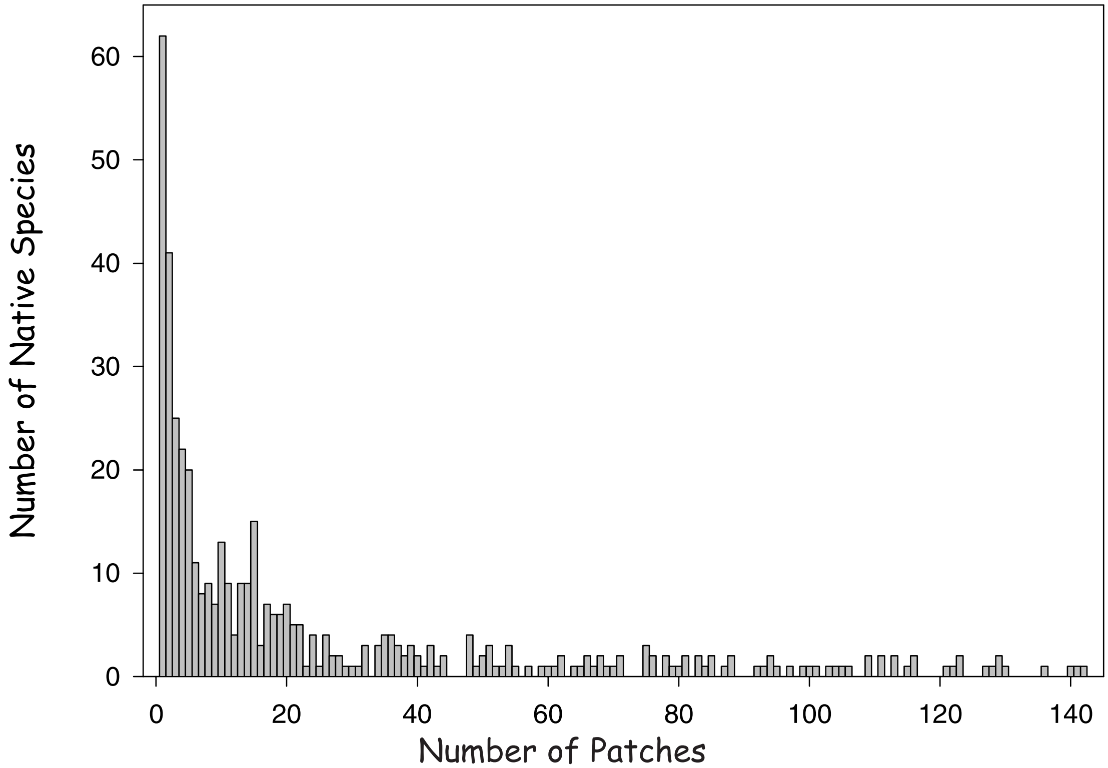


Figure 8. The number of native species (excluding grasses and sedges) that occur in a certain number of patches.

plant species (14% of total) were recorded only once out of the 153 patches while only 18 native species (4% of total) were recorded in at least 75% of the patches (Figure 8). Some of the most common native species include Jack-in-the-pulpit (*Arisaema triphyllum*), Enchanter's Nightshade (*Circaea quadrisulcata*), Sensitive Fern (*Onoclea sensibilis*), Virginia Creeper (*Parthenocissus inserta*), Mayapple (*Podophyllum peltatum*), Poison Ivy (*Rhus radicans*) and Riverbank Grape (*Vitis riparia*).

The number of non-native plant species recorded per patch ranged from one to 81. Of the 143 non-native plant species recorded in the MNHS and the LSWS, 33 non-native species (23% of total) were recorded in only one of the153 patches and only one non-native species (Garlic Mustard - *Alliaria officinalis*) was recorded in at least 75% of the woodland patches (Figure 9). Other common non-native species include Bittersweet Nightshade (*Solanum dulcamara*), Common Buckthorn *(Rhamnus cathartica*), Common Dandelion (*Taraxacum officinale*) and Herb Robert (*Geranium robertianum*).

Figure 10 shows the number of unique species (*i.e.* native and non-native plant species recorded only once) in each physiographic type per sampled area. All physiographic types contained at least one unique native or non-native species except Kame Moraine, which did not have any unique species (*i.e.* all the plant species found in Kame Moraines were found in other physiographic types). This emphasizes the importance of all individual patches and physiographic types in maintaining plant species diversity. More unique native species per sampled area were found in Beach, Till Moraine and Spillway physiographic types while Peat Muck had the highest number of unique non-native species per sampled area.

<u>*Mean Conservatism Coefficient (MCC)*</u>

The mean conservatism score for all plants in a patch reflects the number of conservative species in that patch. In some studies, the conservatism score has been used to assess site quality. For example, the City of London (2000) has developed a methodology for evaluating significant woodlands that uses a MCC threshold of 4.5 to assign a high priority ranking for a woodland patch, 4.0 to 4.5 for medium priority and less than 4.0 for low priority. These values were derived from MCC scores for woodlands inventoried for the LSWS. However, meaningful thresholds for Middlesex County cannot be extrapolated from this data, since sedges (*Carex*), which tend to have high coefficients of conservatism, were not identified in the MNHS. Instead, differences in mean conservatism scores between patches will be used as an indicator of woodland health.

Mean conservatism scores for individual patches ranged from 3.0 to 4.8. Figure 11 shows the frequency distribution of conservatism coefficients for native plant species (excluding sedges) recorded in MNHS and LSWS compared to the distribution of all plants (excluding sedges) recorded in Middlesex County (Oldham 1993). The two frequency distributions are significantly different from each other ($X^2_{0.05, 10} = 18.307$, $X^2_{obs} = 22.097$). The main difference between the two frequency distributions is fewer species with high

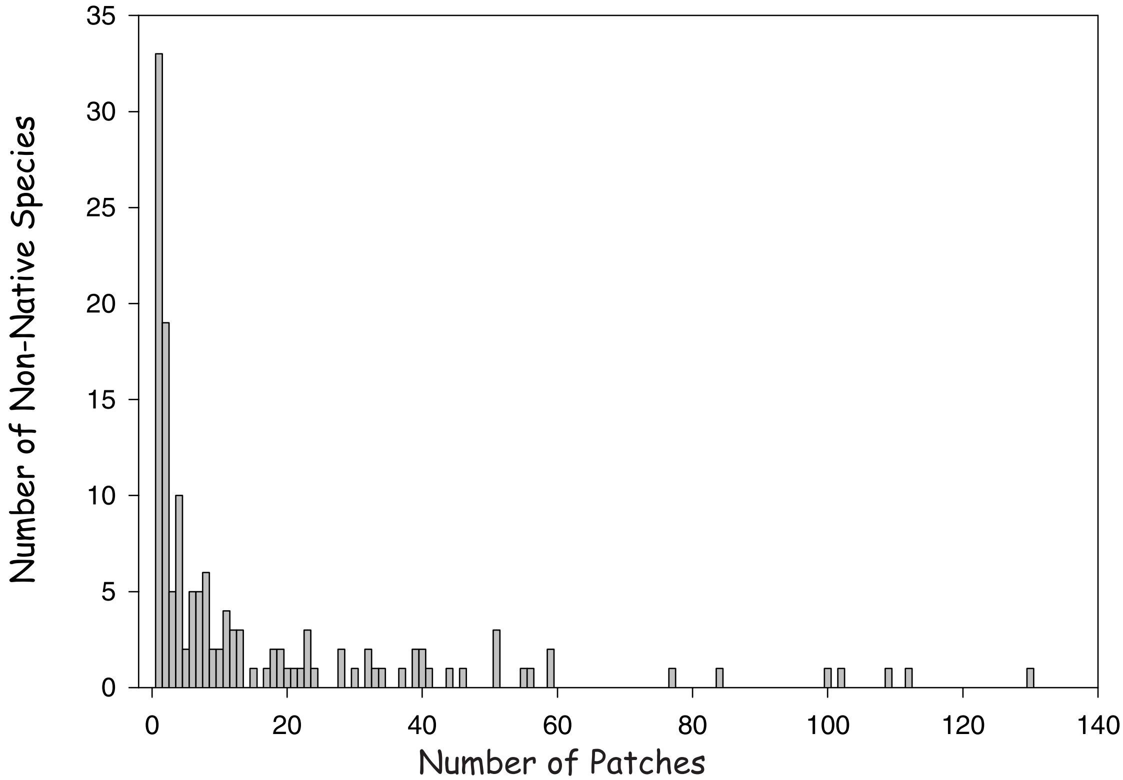


Figure 9. **The number of non-native species (excluding grasses and sedges) that occur in a certain number of patches.**

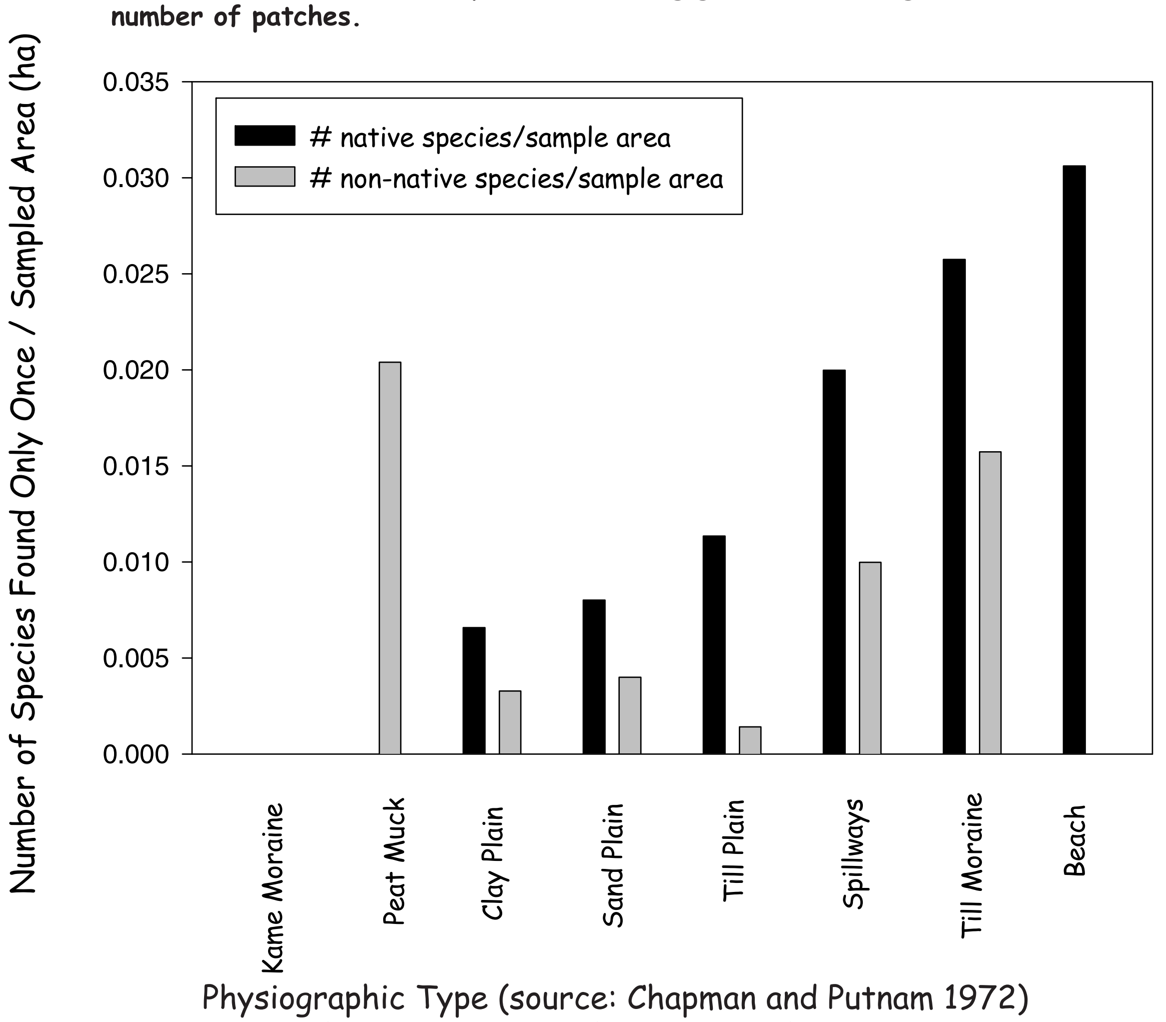


Figure 10. **The number of plant species found only once in Middlesex County per area of physiographic type studied in MNHS and LSWS.**

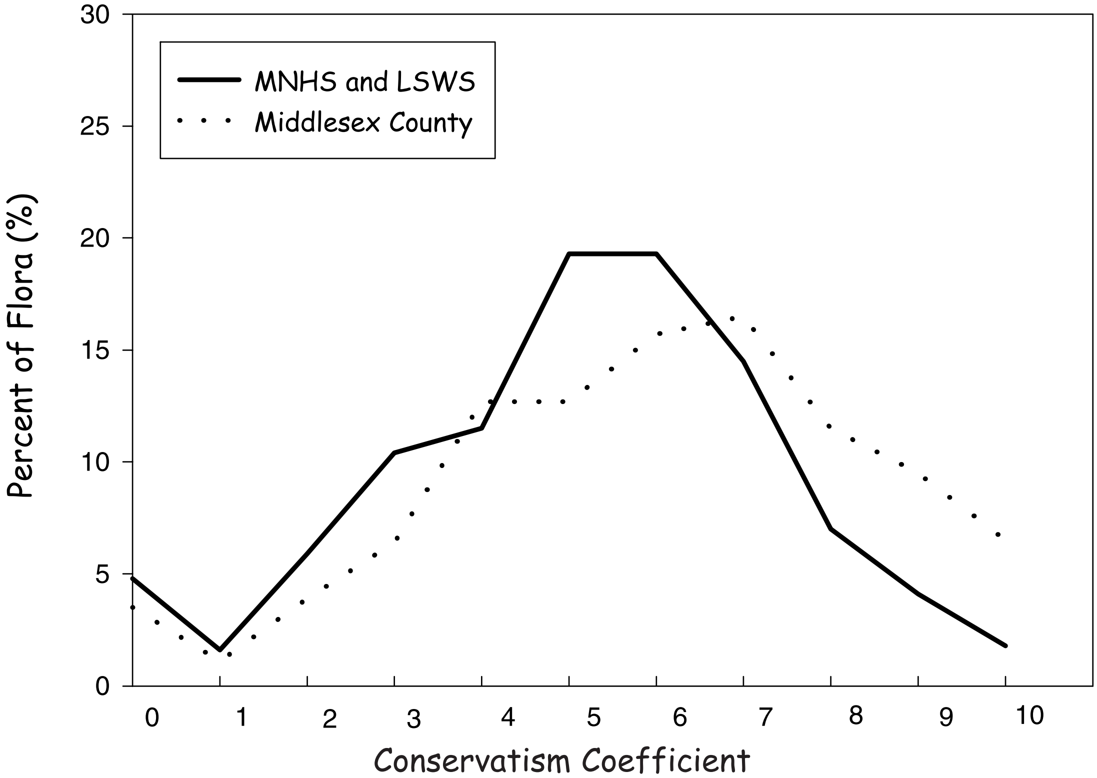


Figure 11. Distribution of the conservatism coefficient for native plant species (excluding grasses and sedges) for all of Middlesex County (source: Oldham *et al.* 1995) and for plants surveyed in the MNHS and LSWS.

conservatism coefficients of 8, 9 and 10 in the MNHS and LSWS compared with County flora. As well, overall mean conservatism for all species in the MNHS and LSWS was 4.6. This is much lower than the mean conservatism score of 6.0 that has been reported for all of Middlesex County (Oldham *et al.* 1995). These differences reflect the fact that the MNHS and LSWS focused on typical woodland patches. Pristine and special areas, where very conservative plants are most likely found, were not specifically targeted in the MNHS and LSWS. However, plants from such areas would be represented in the overall County list.

Weediness

Measures of weediness can be used as indicators of quality since weedy species have the ability to displace native flora and tend to move into disturbed habitats. The majority (50%) of non-native plants recorded for MNHS and LSWS are relatively non-invasive (weediness score of -1), 30% are moderately invasive and 20% are highly invasive (weediness score of -3). This suggests that despite the large number of non-natives recorded in the MNHS and LSWS, many of these species are not highly aggressive and could be contained with minimal control. However, non-native species were not quantified (only presence, not extent, was recorded). Therefore, it is impossible to know whether the few aggressive non-native species were more widespread in the woodland patch than the numerous less invasive non-native species. When weediness scores are broken down into physiographic type (Figure 12), there is a higher patch weediness score per area sampled for Peat Muck, Beach and Spillways compared to other physiographic types. These physiographic types are also often associated with surficial flow, which may aid in the dispersal of non-native seed sources.

Mean Wetness

Wetness scores are not an indication of woodland health, but can be used as a measure of moisture conditions in a woodland patch. Wetness scores range from +5 for native obligate upland species to -5 for native obligate wetland species. Mean wetness coefficients for individual patches surveyed in the MNHS and LSWS ranged from -2.53 to 2.13. Figure 13 shows the distribution of wetness coefficients for native plant species (excluding sedges) recorded in MNHS and LSWS compared to the distribution of all native plants (excluding sedges) recorded in Middlesex County (Oldham 1993). The two distributions are similar, with the exception that there were fewer obligate species (both wetland and upland) recorded in MNHS and LSWS. Approximately half of the native plant species recorded in Middlesex and in the MNHS and LSWS are upland species (coefficient of wetness of +1 to +5) and half are wetland species (coefficient of wetness of -1 to -5). Over 20% are obligate wetland species (coefficient of wetness of -5) and over 20% are obligate upland species (coefficient of wetness of +5). For each patch, the average wetness scores for native herbaceous plant species were lower (*i.e.* more tolerant of moist conditions) than for native tree species (Figure 14).

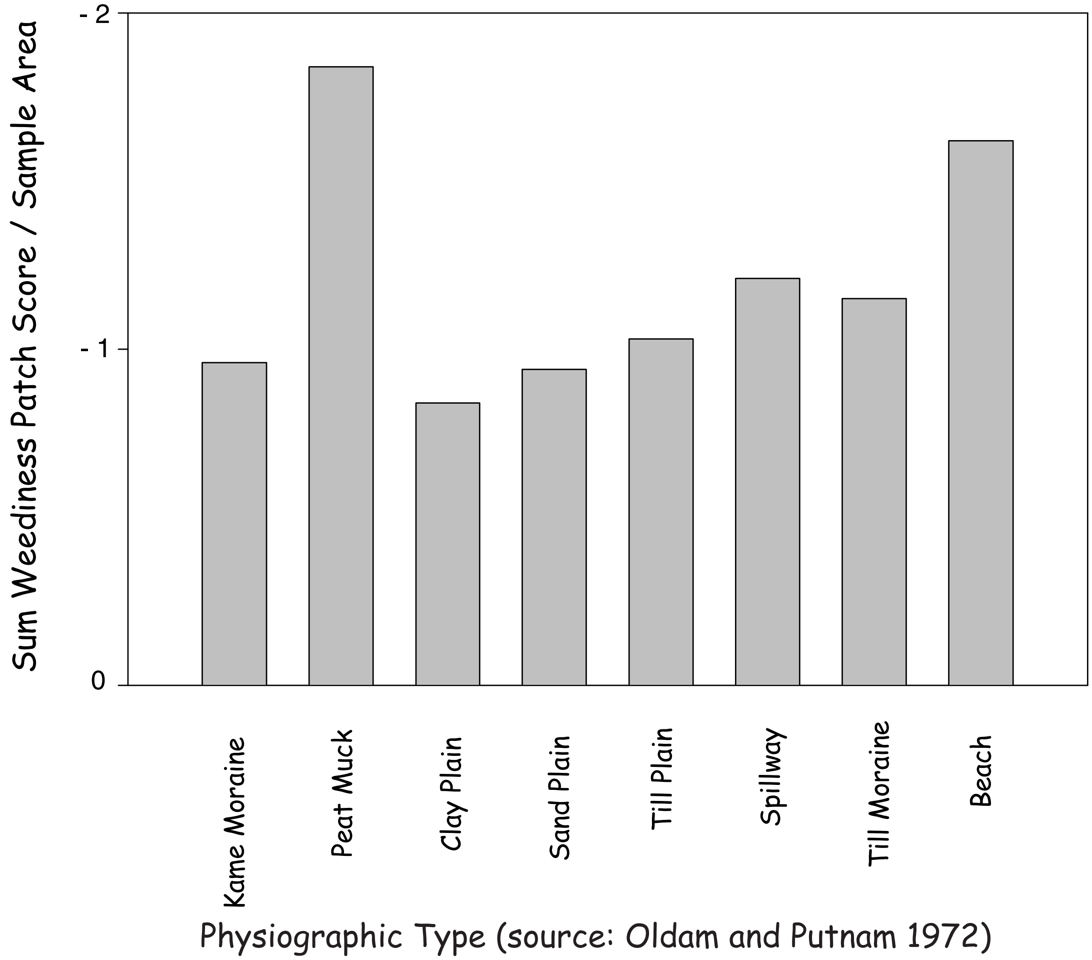


Figure 12. Sum of patch weediness scores per sampled area for each physiographic type.

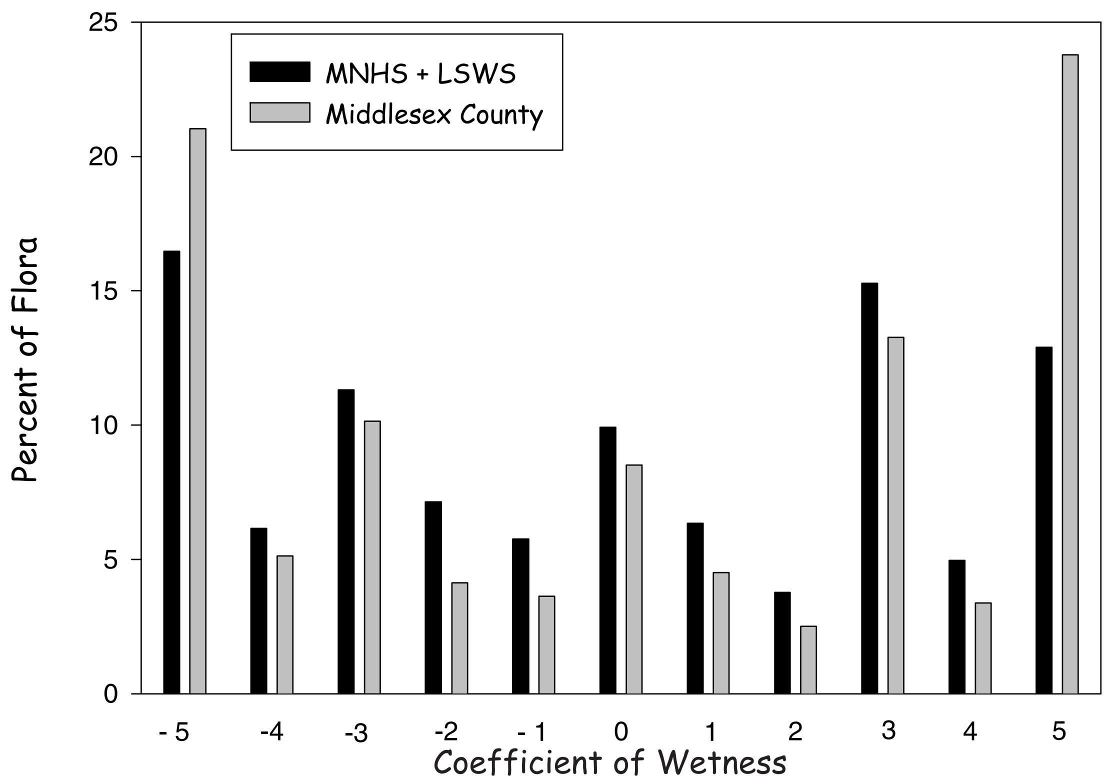


Figure 13. Distribution of the coefficient of wetness for native plant species (excluding grasses and sedges) for all of Middlesex County (source: Oldam *et al.* 1995) and for plants surveyed in the MNHS and LSWS.

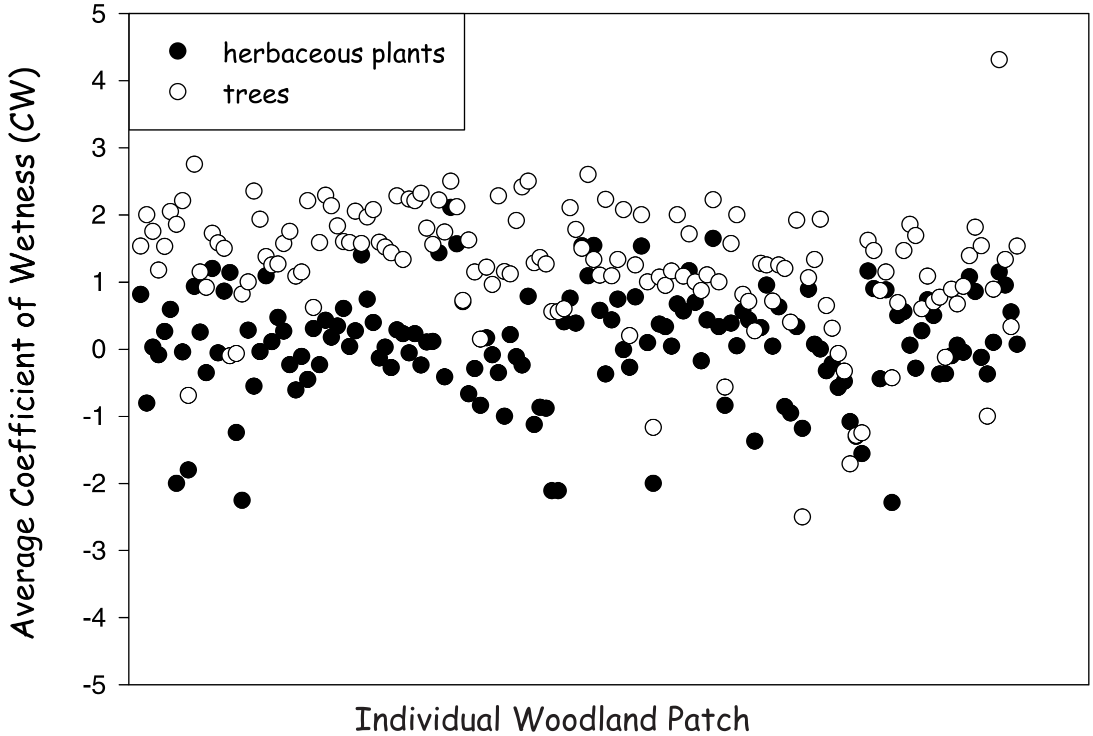


Figure 14. Comparison of the average coefficient of wetness per patch for herbaceous plants and trees.

Variations in moisture regime are related to the differences in soil and physiographic conditions. Table 5 shows the average wetness coefficients for all native plants found in a particular physiographic type for MNHS and LSWS. Peat Muck, Spillways and Kame Moraines have higher proportions of wetland species (larger negative averages for wetness coefficients) whereas Sand and Till Plains have more upland species (larger positive averages for wetness coefficients).

Table 5. The average wetness coefficient for all native plants found in a particular physiographic type.

PHYSIOGRAPHIC TYPE	AVERAGE CW (for MNHS and COLSWS)
BEACH	0.22
CLAY	0.31
KAME MORAINE	-0.56
PEAT MUCK	-1.19
SAND	0.45
SPILLWAY	-0.05
TILL MORAINE	0.2
TILL PLAIN	0.44

4.4.2 Vegetation Communities

An average of two communities per patch were found in MNHS, while an average of eight communities per patch were identified in LSWS. Although the number of vegetation communities described in each patch has been used as a measure of overall habitat diversity (City of London 2000), the discrepancy between the two studies in geographic Middlesex County demonstrates that the number of communities in a patch is not a good measurement of diversity, since the delineation of communities can be subjective.

Despite the discrepancy in the number of communities per patch between the MNHS and the LSWS, general trends in community descriptions can still provide information about the types of habitat remaining on the landscape. Overall, 81% of the community systems inventoried were terrestrial, 62% occurred on tablelands, 95% were on mineral substrate, 57% were of young to mid- successional age and 58% were forests (85% deciduous, 8% coniferous and 7% mixed). Several of the coniferous communities described were plantations.

Seral Age

Seral age of the vegetation communities was generally young, with only 36% of the communities described as mid-aged or older (Figure 15). Forty percent of the communities were described as young while 24% were described as pioneer. Seral refers to the gradual replacement of one plant community by another. Therefore, seral age does not refer to the actual age of the stand, but reflects the composition of the plant community (particularly the tree species) with respect to light tolerance and moisture conditions. For example, young stands will contain fewer shade tolerant species than mid-aged stands. The distribution of successional ages across Middlesex County suggests that the forests are mainly in a disturbed successional condition, either still recovering from heavy logging or forming second growth from previously cleared land. Mature community types appear to be under-represented in Middlesex County.

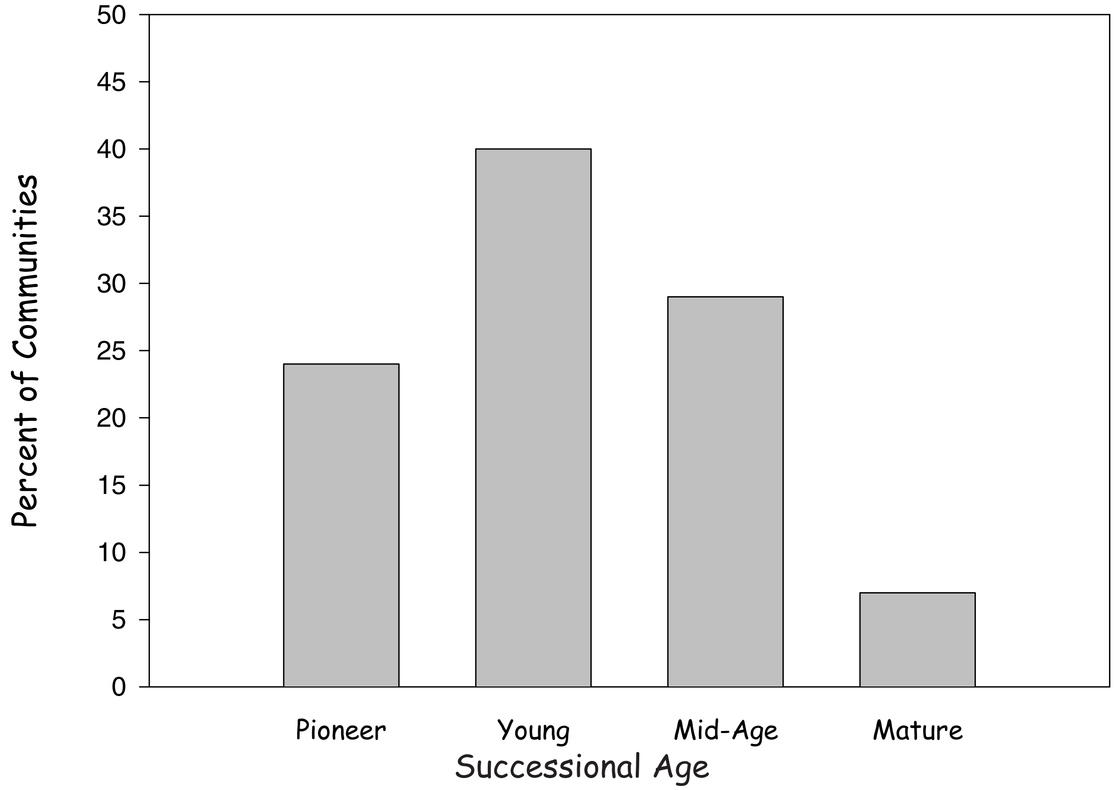


Figure 15. Proportion of woodland communities of a particular successional age.

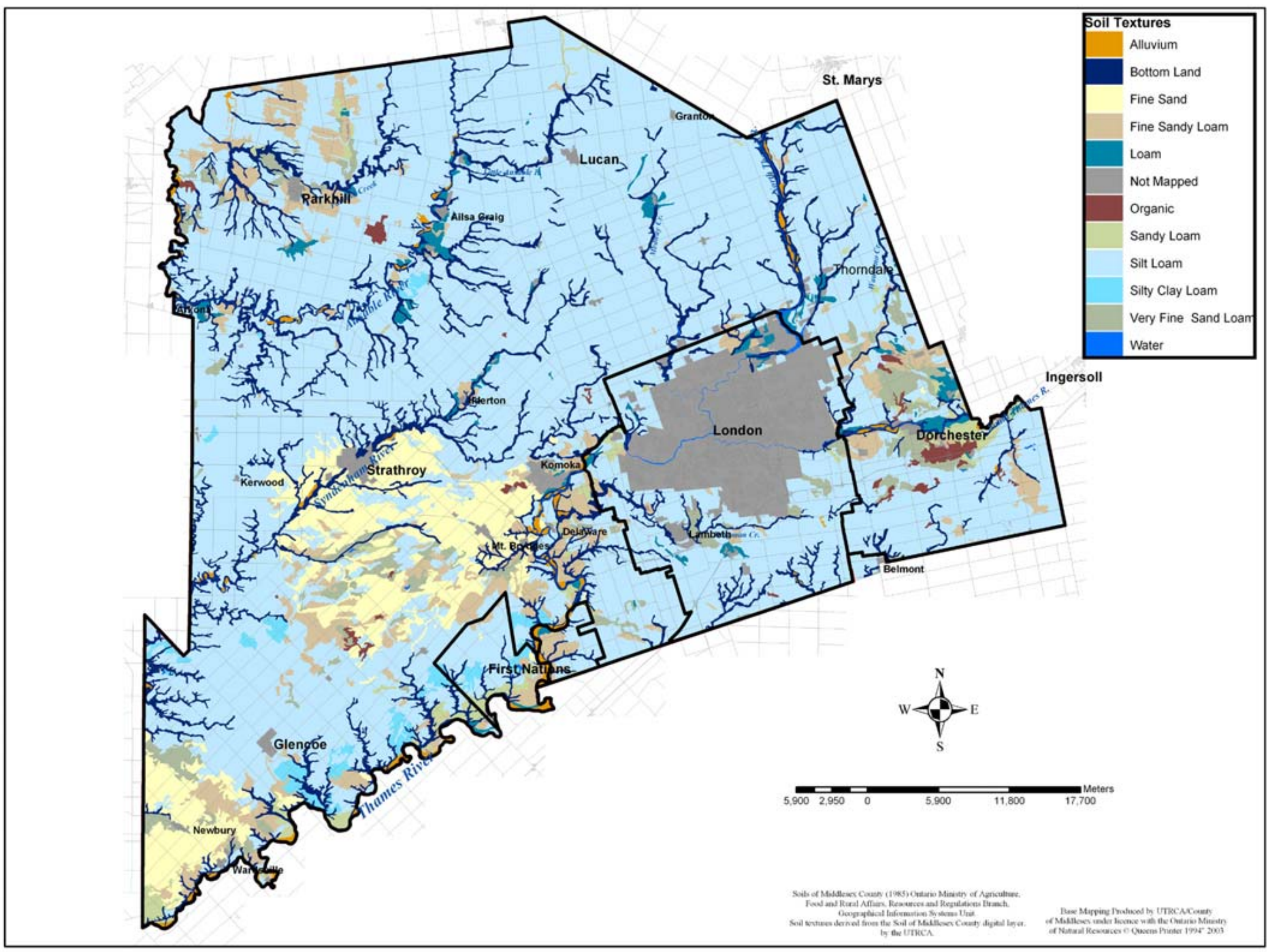


Figure 16. Soil Textures of Middlesex County.

Soil Type and Moisture

Figure 16 shows that the prevailing soil in Middlesex County is loam, which has developed on medium-textured glacial till and is imperfectly drained. A comparison of mineral soil pore patterns between field surveys and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA 1985) soils map for the 68 surveyed patches in the MNHS shows that the soils tend to be more retentive in the field than is depicted on the soils map. Since soil mapping is done at generalized scales (*e.g.* 1:50,000), they cannot be relied on to give definitive soil properties such as soil moisture and texture at finer, site specific levels.

Soil information from LSWS was not included in the analysis since measurements of soil texture and moisture did not follow the same methodology as MNHS. Most woodland patches surveyed in the MNHS tend to remain on imperfectly drained soil. Approximately 66% of the woodland patches occurred on loam or silty loam (a retentive pore pattern), 10% on sandy loam or loamy very fine sand (a moderately retentive pore pattern), 2% on silty clay loam (a very retentive pore pattern) and 22% on fine sand or loamy fine sand (a moderately open pore pattern).

Basal Area

In a forest managed for optimum tree growth, there should be a mixture of trees of different sizes and a residual basal area of 15 - 20 m^2 / ha (OMNR 1983). Since basal area accounts for both the number of standing trees per hectare and their size, the same basal area may be achieved by many small trees or fewer large trees. Figure 17 shows a) the size class distribution of upland hardwood trees in Middlesex County and b) the recommended residual size classes for upland hardwood trees according to the provincial standard (OMNR 2000b). The size class distribution of trees in Middlesex County shows an over abundance of small trees (*i.e.* high basal area) and too few trees in the largest size classes (*i.e.* low basal area) compared with the provincial standard. Similar findings of sub-optimal forest conditions in the Maitland River watershed were attributed to the practice of diameter limit cutting (Bowles *et al.* 2001).

Figure 18 shows the frequency distribution of basal areas of trees > 25 cm dbh in upland hardwood sites in Middlesex County to determine how many communities meet the recommended basal area for these larger trees. Larger trees are important to the health of the woodland for many reasons. They act as seed sources, they provide habitat and food for wildlife and they enhance the amount of woody material. The provincial standard recommends that the post logging basal area of trees of this size should be 15 m^2 / ha (OMNR 2000b). Approximately 55% of the upland forests in Middlesex County fall below the standard. Figure 19 shows the basal area of larger trees (> 25cm diameter) plotted against average size of trees in Middlesex County. Many woodlands have basal areas lower than the 15 m^2 / ha optimum, and the average tree diameter is smaller than the allowable diameter limit (Middlesex County Tree Cutting Bylaw No. 4672).

Diameter limit cutting does not restrict the number of trees cut, nor does it consider what the residual basal area should be. Instead, all healthy trees over a certain minimum diameter are harvested. Under diameter limit logging, the remaining canopy is more open. This encourages stems to develop low branches, opens the remaining forest to wind throw and disease, causes growth in diameter rather than height and produces an even-aged stand with an overstocking of small stems. The forest is often not harvestable again for several decades.

Given the results of the MNHS (Figures 17 to 19), it is recommended that a better harvesting technique for Middlesex County would be “selection cutting” for diversity in size and species composition to encourage maximum timber growth, improve timber quality and enhance wildlife values of the forest (OMNR 2000b). Under this type of harvesting, individual trees are marked by a certified marker prior to harvest. The composition and amount of tree harvesting can be amended to maintain or enhance timber production. For example, single-tree selection is most appropriate for promoting growth and development in upland stands of shade-tolerant hardwood species such as Sugar Maple and American Beech (OMNR 2000b, 2002a), while group selection may be more appropriate for mid-tolerant species such as oak, hickory, Sassafras, Tulip Tree and Hackberry that require larger canopy openings for regeneration and development (Elliot *et al.* 1997, Miller *et al.* 1995, Law and Lorimer 1989).

Forest stands that have been cut through selection methods have more rapid overall growth and good natural regeneration. The greater structural diversity of selection cutting for size and species composition creates numerous vegetation layers that are important to maintaining plant and animal species diversity. These features are achieved by employing a suite of forest management practices and application of appropriate silvicultural systems (OMNR 2000b). For example, forest management practices can be modified to allow forests to mature to the late seral stage, by creating canopy gaps 10 - 50 metres in diameter to encourage growth of mid-tolerant species, retaining cavity trees and snags, increasing the amount of woody material, leaving a minimum of three trees larger than 50 cm in diameter in each hectare, retaining higher basal areas in the largest diameter classes and extending the period between harvests (OMNR 2003). Animal and plant species diversity can be maintained or enhanced by protecting areas of high conservation value, such as areas that contain provincially rare flora and fauna, woodland areas > 90 years of age and areas that contain forest interior.

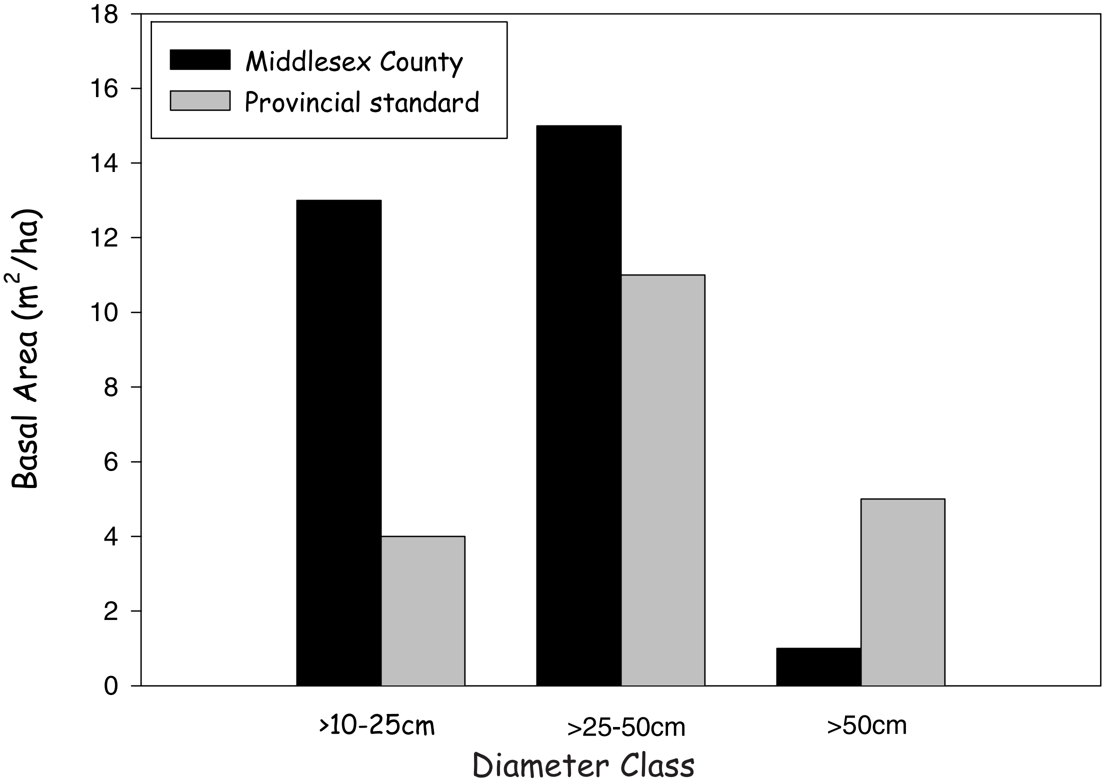


Figure 17. **Diameter size class distribution of upland hardwood trees in Middlesex County compared with the recommended residual diameter size class according to the provincial standard (OMNR 2000b).**

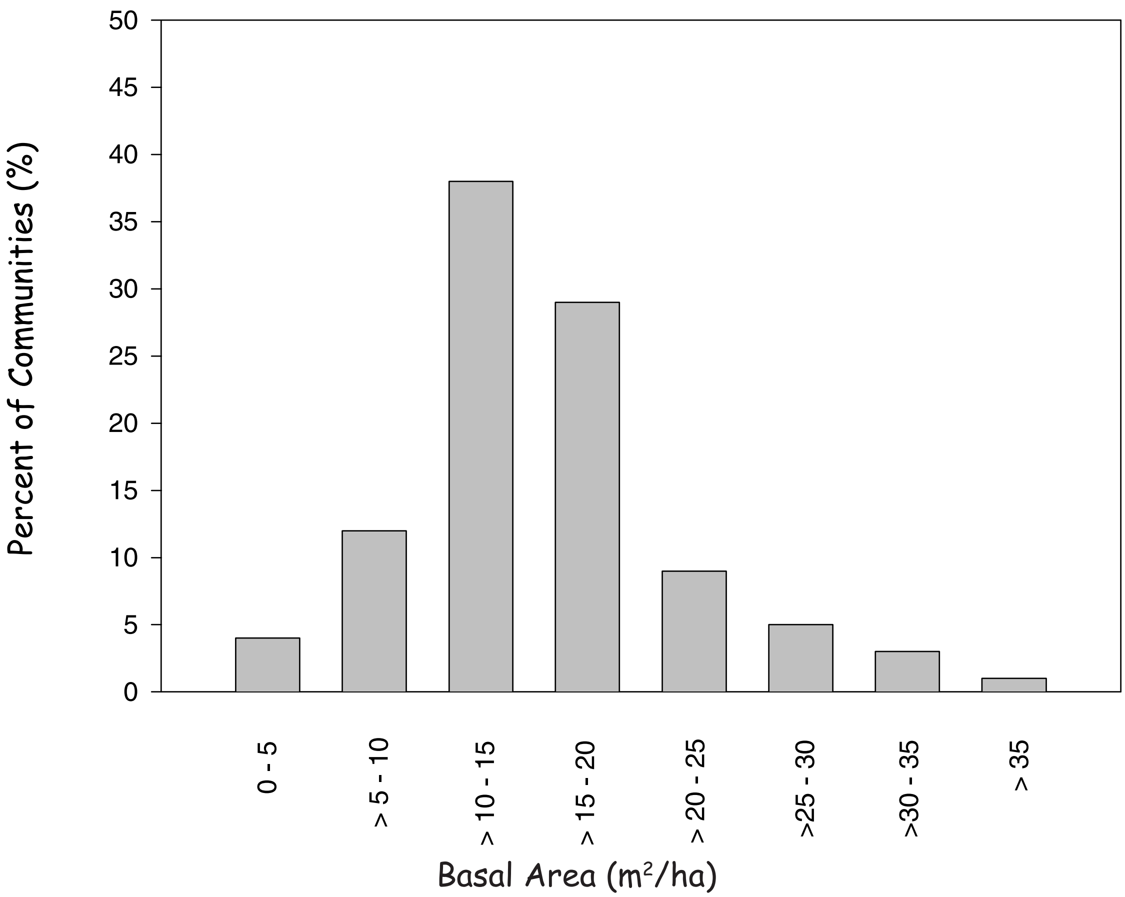


Figure 18. **Basal area distribution of medium and large trees (*i.e.* >25 cm DBH) in upland hardwood woodland patches surveyed in MNHS.**

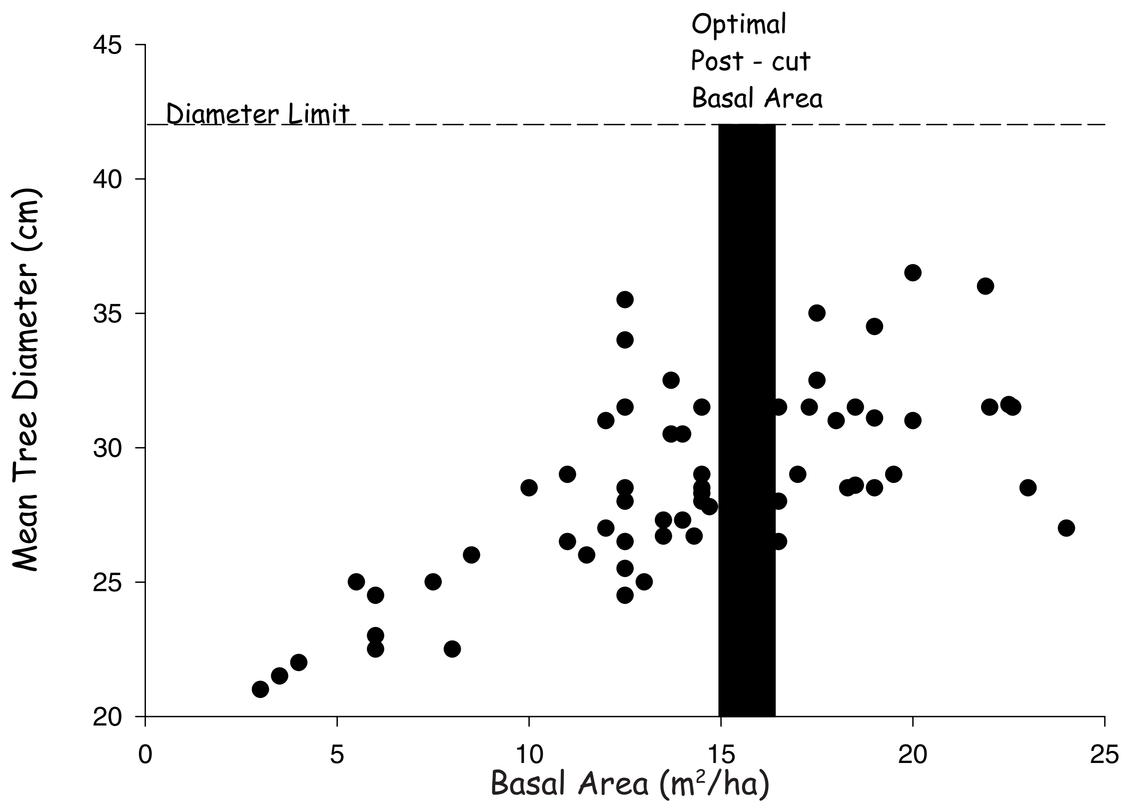


Figure 19. **Basal area of medium and large upland trees (i.e. >25 cm DBH) plotted against average tree size for forest communities surveyed in MNHS (reprinted from Bowles 2002).**

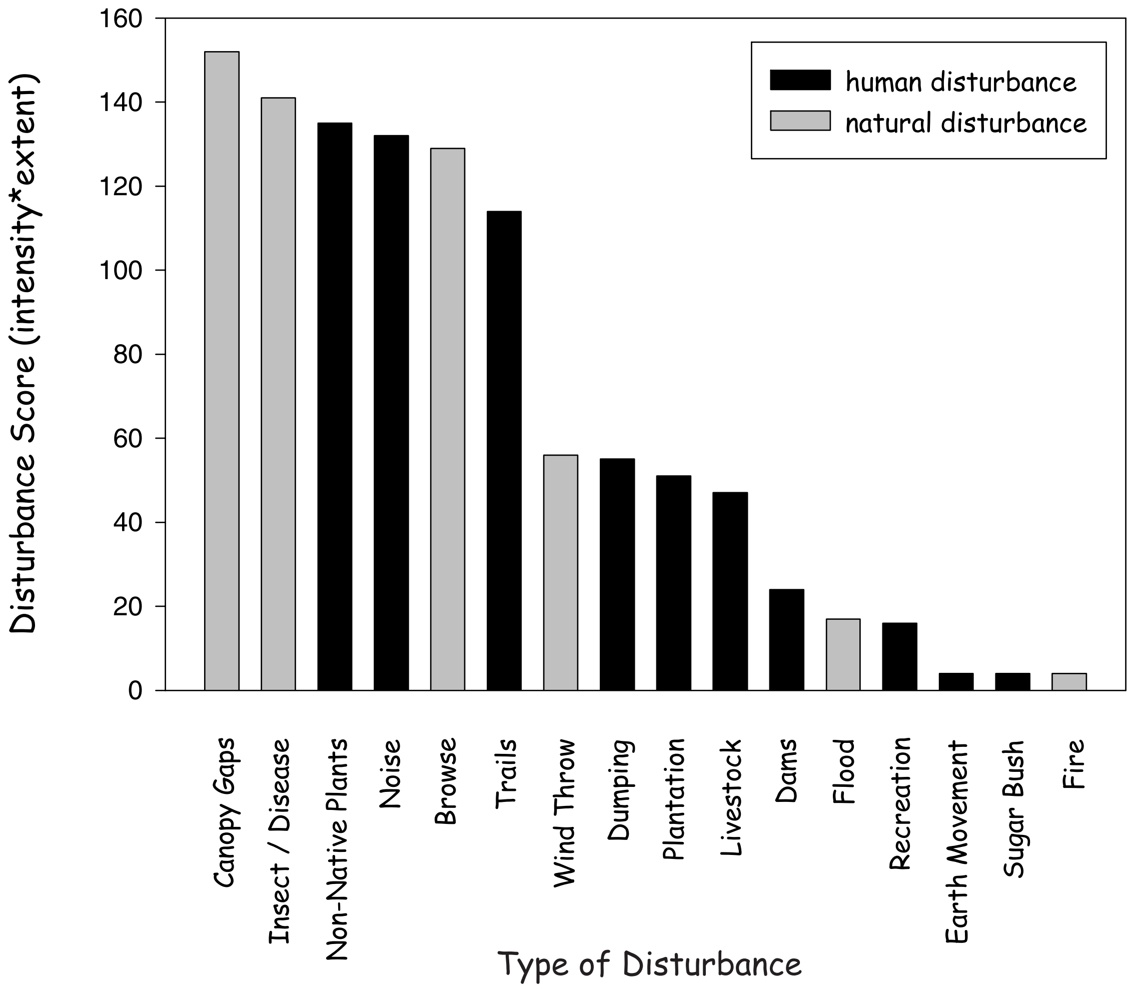


Figure 20. **Disturbance scores summed over all woodland patches surveyed in MNHS.**

4.4.3 Woodland Patch Type

Disturbance

Disturbance events may have an important influence on overall site quality. Disturbance events were considered to be perturbations of the natural community dynamics and, therefore, a negative influence on overall woodland patch health. Figure 20 shows the disturbance scores (*i.e.* disturbance index summed over all surveyed patches) for the various types of disturbance recorded in MNHS. Natural disturbance processes such as disease, canopy gaps and wildlife browse were most prevalent and intense while fire and flood were least. Human disturbance types such as hiking trails, non-native plant species and noise were most prevalent and intense while sugar bush operations, earth movement and recreation activities other than hiking (these were examined separately) were least.

The natural disturbance index had a mean of 7.2 (± 0.3 S.E.) and ranged from 4 to 19 points. The human disturbance index had a mean of 8.4 (± 0.5 S.E.) and ranged from 2 to 18 points. However, the human disturbance index was more variable than the natural disturbance index (over 90% of the patches had human disturbance scores between 4 and 14 while most of the patches had natural disturbance scores between 5 and 10). The variability expressed in human disturbance values demonstrates the difficulty in assessing extent and intensity of human disturbance in remnant forest patches on the landscape, since different types of human disturbance can have various effects depending on the type of vegetation, the features and functions of the woodland patch, the topographic location, *etc.* This variability may also reflect how different landowners use their woodlands. The effects of natural disturbance were not as variable since the woodland species have had many years to adapt to these types of disturbances. There was no correlation between natural and human disturbance indices for each patch ($r^2 = 0.0066$, $t_{0.05(2),67} = 1.995$, $t_{obs} = 0.675$).

4.5 RESULTS OF THE MAPPING AND GIS ANALYSIS

4.5.1 Woodland Patch Size

Figure 21 shows the distribution of woodland patches by size in the county. In general, there are many patches in small size classes and fewer in large size classes (Figure 21a). More than 90% of Middlesex County's woodlands and wetlands fall into the "micro" category, between 4 and 40 hectares, as defined by Riley and Mohr (1994). More significant is the fact that over 50% of the County's woodlands are less than 4 hectares. However, when one looks at the percent of area accounted for by various size classes, over 50% of the woodland and wetland area is accounted for by patches > 25 ha in size, while less than 5% is accounted for by the smallest size class (Figure 21b). Therefore, the few large woodland patches on the landscape (*i.e.* patches > 25 ha) account for most of the woodland area in Middlesex County. Figure 21 demonstrates that by protecting only the larger patches, there would be a significant loss of a large number of woodlands.

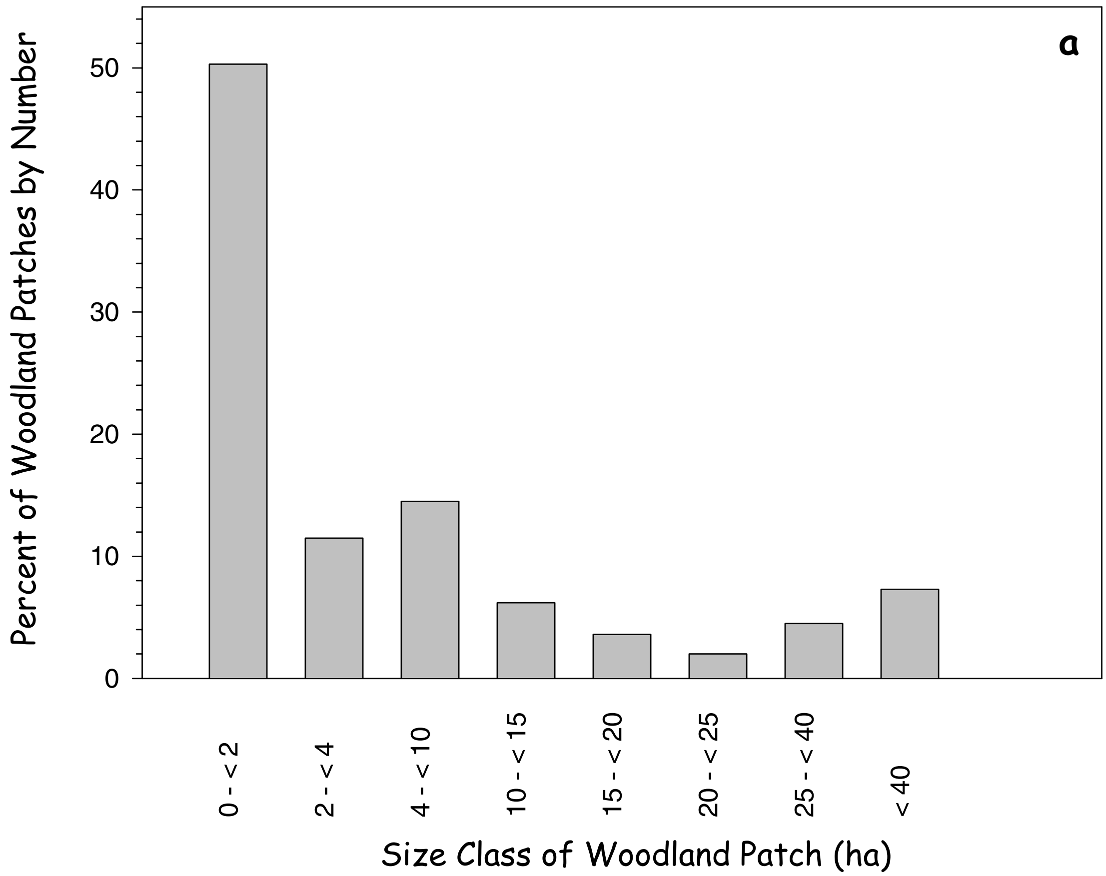
4.5.2 Woodland Patch Interior

Numerous functions are attributed to woodland patches with forest interior, including reduction of detrimental edge effects such as sun scald, windfall and invasive species, as well as habitat for area sensitive species. Wilcove (1988) and Harris (1984) have shown that physical edge effects (*i.e.* microclimate, sun scald, noise, wind, dessication) extend into a forest to a distance of three times the height of the trees in the forest. Mature trees in Middlesex County reach a height of approximately 25 - 30 m. Therefore, forest interior (core patch area) is defined as the amount of area remaining after 100 m buffer is removed from around the patch perimeter (Figure 6).

Of the 1078 woodland patches that have interior, approximately 50% have less than 2 ha of interior area (Figure 22). In general, there are many small interior size classes and fewer large interior size classes. The largest amount of interior area recorded for a patch was 205 ha. The majority of woodland patches with large amounts of interior are situated in the northwest section of Middlesex County in the Ausable Bayfield watershed. These woodland patches occur along river valleys and bottom lands. Figure 23 shows the amount of interior for patch sizes between 6 and 15 ha in size. From this figure, we see that patches must be between 10 and 12 ha in size before an interior size of at least 2 ha is found. On the other hand, many of the woodland patches on the landscape are long and thin, which means that although they might be of a relatively large area, they may not have much interior.

4.5.3 Forest Connectivity

Linkages are important for both animal and plant dispersal. However, the identification of landscape connectivity is an evolving science. For Middlesex County, 100 m is the distance at which linkages between woodland patches greater than 10 ha start to appear (Figure 24). One hundred metres is also the distance which most seeds dispersed by wind can travel (Nathan *et al.* 2002). At least 50% of the woodland patch must be within 100 m of a woodland patch greater than 10 ha to ensure that there is linkage between the two patches.



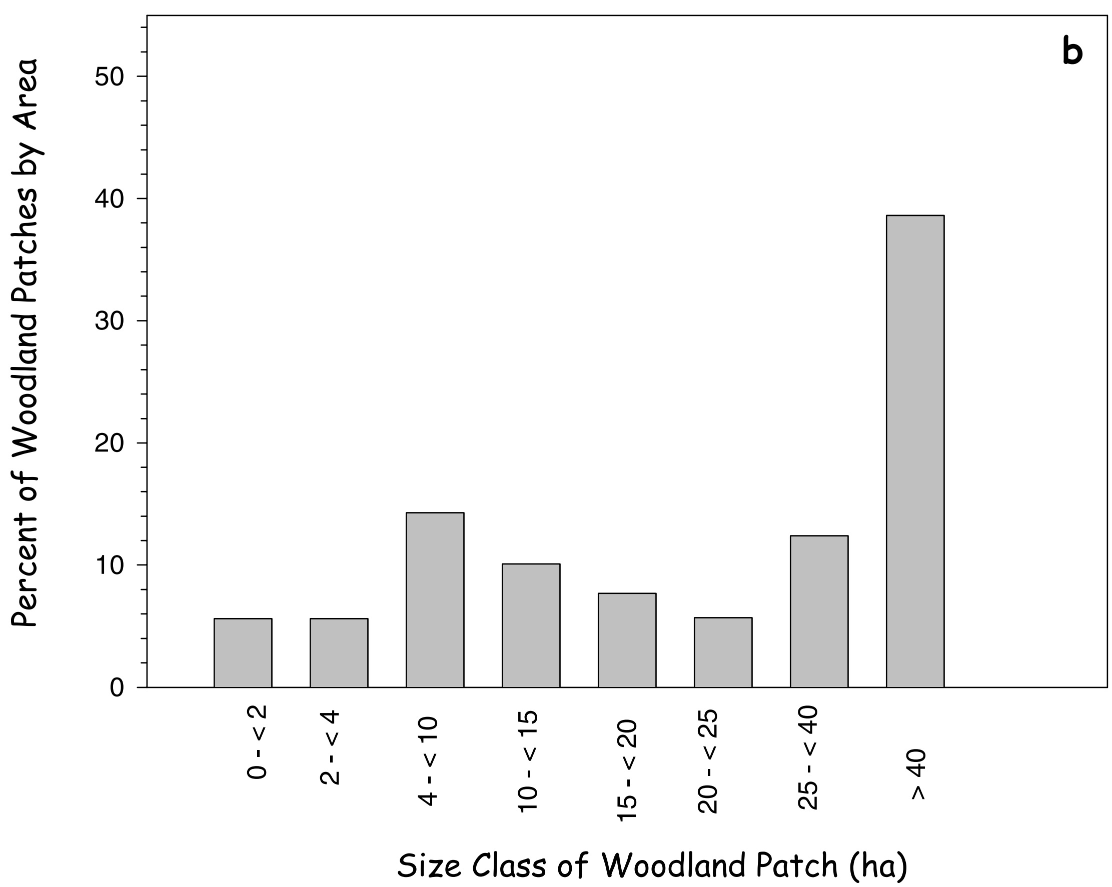


Figure 21. The distribution of woodland patch size class in Middlesex County by a) the number of woodland patches and b) the total area of woodland patches.

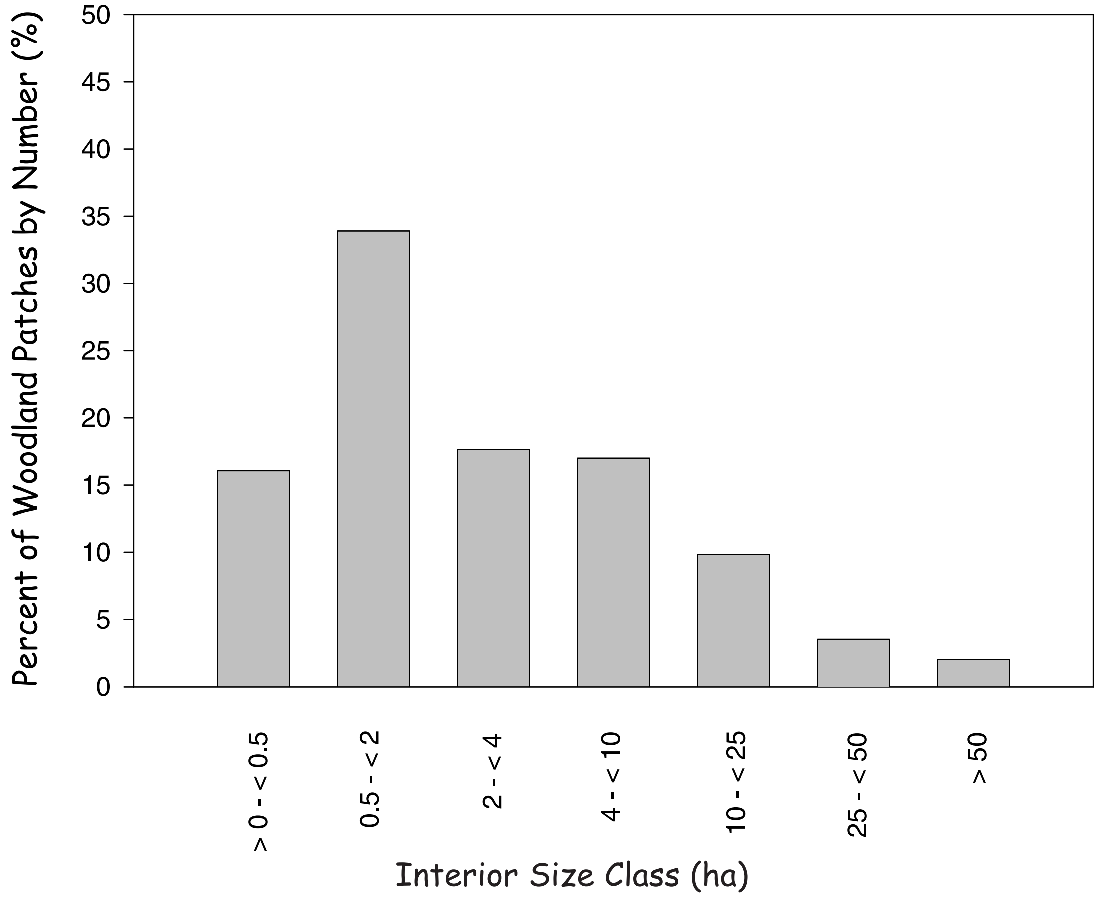


Figure 22. Distribution of interior size classes for woodland patches in Middlesex County.

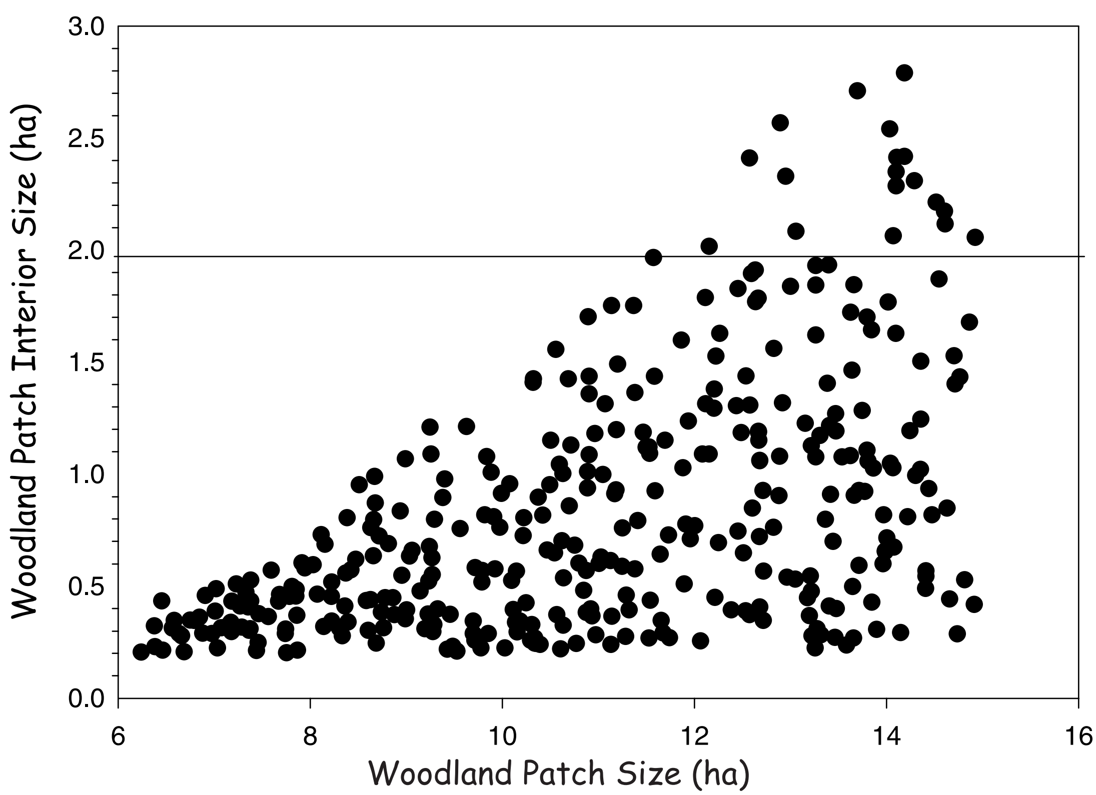


Figure 23. The amount of interior for patch sizes between 6 to 15 ha in area.

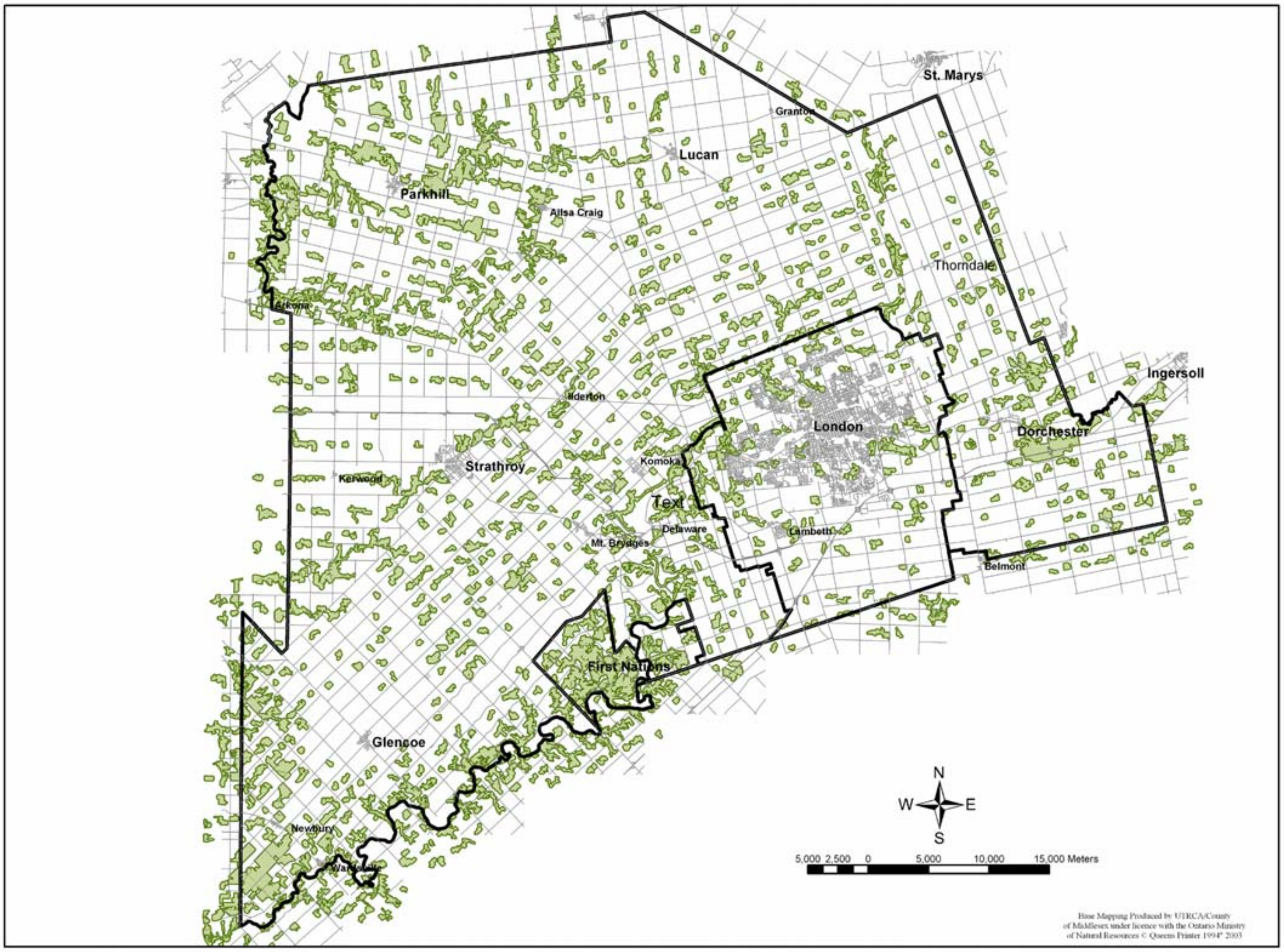


Figure 24. Woodland patches in Middlesex County that are greater than 10 ha and buffered by 100 m on outside of patch.

4.6 RESULTS OF THE STATISTICAL ANALYSIS

There was a significant relationship (*i.e.* $F_{obs} > F_{crit}$) between species richness, weediness and conservatism coefficient and all landscape parameters, with the exception of nearest neighbour greater than 10 ha. However, only species richness (native and non-native) and sum of weediness scores showed a relatively strong relationship (*i.e.* $r^2 > 0.36$) with the independent landscape variables. One reason that nearest neighbour did not have a significant relationship with any of the woodland patch indicators of health could be the fact that most woodlands are relatively equi-distant from each other, reflecting the non-random pattern of remnant woodland patches on the landscape.

4.6.1 Native Species Richness

Table 6 shows the relationship between the number of native species per patch and patch area, patch interior, distance to any road (*i.e.* all provincial, county and township roads), distance to main road (*i.e.* only provincial and county roads), distance to ANSI and distance to wetland (PSW and LSW). The regression was significant ($F_{0.05(1),6,118} = 2.18$, $F_{obs} = 18.38$).

The number of native plant species had a significant positive relationship to area of the woodland patch, demonstrating that larger patches have more native species. However, the number of native plant species had a significant negative relationship to amount of interior, which means that patches with more interior had fewer native species than the same size patch with less interior. Since interior conditions tend to be relatively undisturbed and well shaded, it is expected than only specific interior native species would be able to grow in these conditions and that woodland patches with more edge habitat would have higher numbers of native species.

There was a significant negative relationship between the number of native plant species and distance to any road. In other words, the shorter the distance between the woodland patch and any road, the greater the number of native species. Roads may be acting as corridors for species dispersal. However, there was no significant relationship between the number of native plant species and distance to only main roads. The higher level of disturbance and maintenance associated with larger roads may be responsible for the lack of relationship.

The number of native plant species had a significant negative relationship to distance from a recognized natural heritage feature (*i.e.* ANSI and wetland). In other words, the shorter the distance between the woodland patch and a recognized natural heritage feature, the greater the number of native plant species in the woodland. ANSIs, which tend to have a higher proportion of conservative native species than non-native species, may be acting as a seed source for nearby woodlands. Recognizing that water can act as a form of species dispersal and many wetlands are associated with surficial flow, it is understandable that seeds from native plants are likely to be dispersed between wetlands and nearby woodlands.

Table 6. Regressional analysis table showing relationship between native species richness per patch and the independent landscape variables. Asterisk (*) denotes significance.

R square	0.48
Observations	125
F_{obs}	18.38*
$F_{0.05(1),6,118}$	2.18
$t_{0.05,118}$	1.66

INDEPENDENT VARIABLES	COEFFICIENTS	STANDARD ERROR	|t OBSERVED|
Patch Area	1.75	0.21	8.28*
Patch Interior	-1.91	0.82	2.32*
Any Road Distance	-27.9	13.44	2.07*
Main Road Distance	-0.85	2.54	0.33
ANSI Distance	-2.5	1.09	2.28*
Wetland Distance	-3.33	1.4	2.38*

4.6.2 Non-Native Species Richness

Table 7 shows the relationship between the number of non-native species per patch and patch area, patch interior, distance to any road (*i.e.* all provincial, county and township roads), distance to main road (*i.e.* only provincial and county roads), distance to ANSI and distance to wetland (PSW and LSW). The regression was significant ($F_{0.05(1),6,118} = 2.18$, $F_{obs} = 11.35$).

The number of non-native plant species was also significantly positively related to area of the woodland patch, demonstrating that larger patches have more non-native species. The number of non-native plant species had a significant negative relationship to amount of interior, demonstrating that patches with interior have fewer non-native species. Since many non-native species are opportunistic and adapted to disturbances, which are often prevalent in edge habitats, the more stable conditions found in patches with interior forest habitat would be less suitable for non-native species.

The number of non-native plant species was significantly negatively related to distance from a road. In other words, woodland patches closer to roads have more non-native species. Roads may be acting as corridors for species dispersal. Although the relationship between only main roads and non-native species was stronger than with native species, it was still not significant.

The number of non-native plant species was significantly positively related to the distance from an ANSI. In other words, woodland patches closer to ANSIs have fewer non-native species. ANSIs, which tend to have a higher proportion of conservative native species than non-native species, are not contributing non-native seeds to nearby woodlands.

The number of non-native plant species was significantly negatively related to distance from a wetland. In other words, woodland patches closer to wetlands have more non-native species. Recognizing that water can act as a form of species dispersal, it is understandable that seeds from non-native plants are likely to be dispersed between wetlands and nearby woodlands since many wetlands are associated with surficial flow.

Table 7. Regressional analysis table showing relationship between non-native plant species and the independent landscape variables. Asterisk (*) denotes significance.

R square	0.37
Observations	125
F_{obs}	11.35*
$F_{0.05(1),6,118}$	2.18
$t_{0.05,119}$	1.66

INDEPENDENT VARIABLES	COEFFICIENTS	STANDARD ERROR	t STATISTIC
Patch Area	0.46	0.07	6.11*
Patch Interior	-0.79	0.3	2.66*
Any Road Distance	-10.33	4.88	2.12*
Main Road Distance	-0.73	0.92	0.8
ANSI Distance	1.52	0.4	3.84*
Wetland Distance	-1.14	0.51	2.24*

Species Richness and Patch Size

Since patch size appears to account for much of the variation observed in species richness, an Analysis of Variance (ANOVA) was used to determine if species richness differed significantly between woodland patch size classes (Table 8). Differences between woodland patch sizes were significant for both total number of native species ($F_{0.05(1),8,315} = 1.97$, $F_{obs} = 7.21$) and total number of non-native species ($F_{0.05(1),8,315} = 1.97$, $F_{obs} = 6.41$).

Figure 25 shows the relationship between the number of native and non-native species with woodland patch area. Although the regressions are significant for both native species richness ($F_{0.05(1),1,136} = 3.92$, $F_{obs} = 83.98$) and non-native species richness ($F_{0.05(1),1,136} = 3.92$, $F_{obs} = 36.04$), the strength of the relationship is greater for native species ($r^2 = 0.4$) than for non-native species ($r^2 = 0.18$). In general, the larger the woodland patch area, the greater the number of plant species (both native and non-native).

Table 8. Total native and non-native plant species richness, mean number of native and non-native plant species per woodland patch and mean conservatism per woodland patch in nine woodland patch size classes.

Patch Size (ha)	>4	4-10	11-15	16-20	21-25	26-30	31-35	35-40	>40
Total number of native species	170	325	271	301	297	293	274	210	404
Total number of non-native species	42	97	66	80	94	84	62	48	122
Mean number native species per patch	44	59.6	68.8	83.3	88.3	89.2	127.2	92.2	19.4
Mean number of non-native species per patch	8.4	12.8	12.7	14.1	17.6	18.6	24	18.8	31.3
Mean conservatism per patch	3.7	4	4	4.2	4.2	4.1	4.4	4	4.1

4.6.3 Weediness

Table 9 shows the relationship between the weediness score for a patch and patch area, patch interior, distance to any road (*i.e.* all provincial, county and township roads), distance to main road (*i.e.* only provincial and county roads), distance to ANSI and distance to wetland (PSW and LSW). The regression was significant ($F_{0.05(1),6,118} = 2.18$, $F_{obs} = 11.01$).

The sum of weediness scores per patch had a significant negative relationship to patch area. In other words, larger woodland patch areas tend to have more aggressive non-native plant species (*i.e.* more negative weediness scores) than smaller woodland patches. However, the sum of weediness scores per patch had a significant positive relationship to patch interior, showing that woodland patches with interior have less aggressive non-native plant species (*i.e.* more positive weediness scores). Thus, larger woodlands with no interior (*i.e.* a large area of edge) will have more aggressive non-native species than woodland patches of the same size with interior.

The sum of weediness scores per patch was significantly positively related to distance to nearest road. In other words, the farther the woodland patch is situated from the road, the less aggressive (*i.e.* more positive weediness scores) the non-native plant species. Again, there was no significant relationship between the number of native plant species and distance to only main roads.

The sum of weediness scores per patch was significantly negatively related to distance to ANSIs. In other words, woodland patches closer to ANSIs have fewer highly aggressive species (more positive weediness scores) than woodland patches farther from ANSIs.

The sum of weediness scores per patch was significantly positively related to distance from a wetland. In other words, woodland patches closer to wetlands have more highly aggressive species (more negative weediness scores) than woodland patches farther from wetlands.

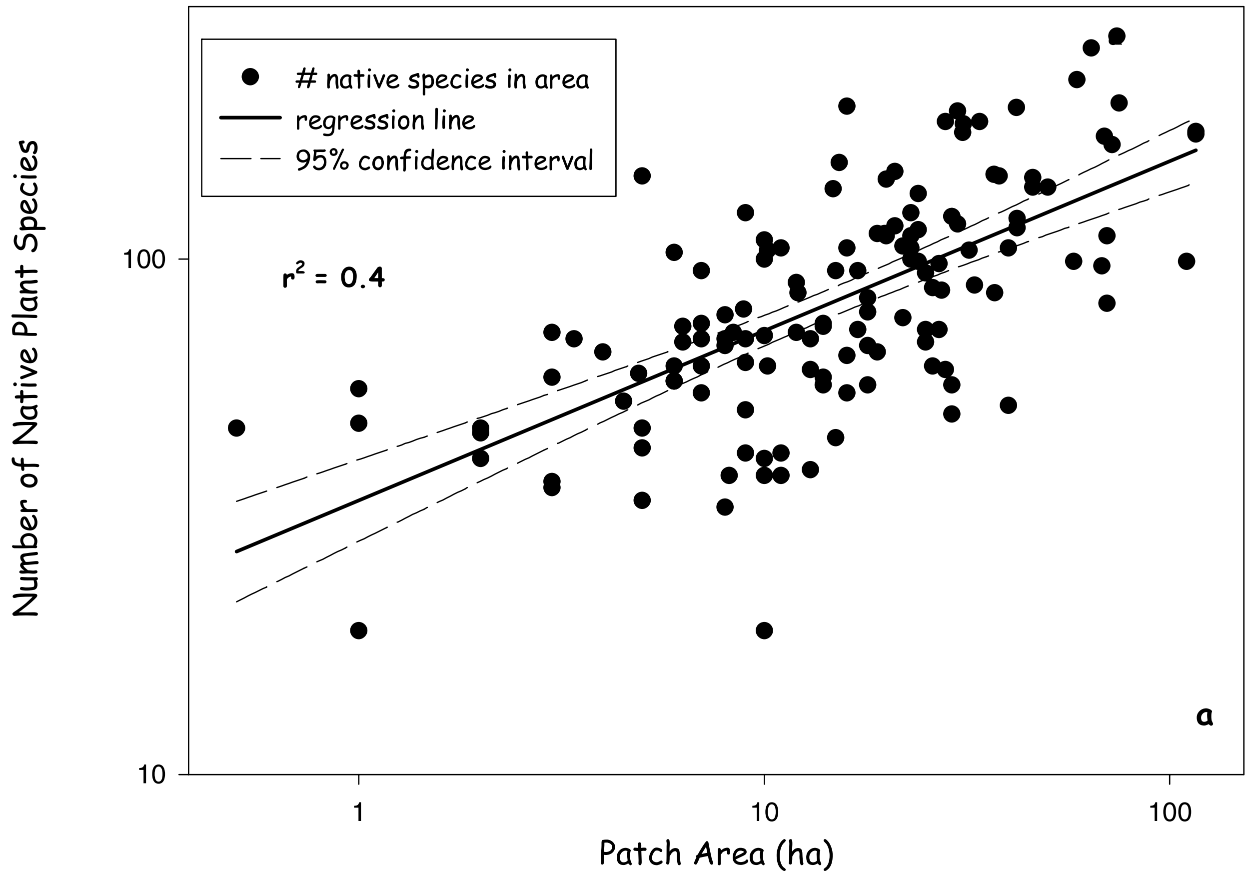
Table 9. Regressional analysis table showing relationship between sum of weediness scores per patch and the independent landscape variables. Asterisk (*) denotes significance.

R square	0.36
Observations	125
F_{obs}	11.01*
$F_{0.05(1),6,118}$	2.18
$t_{0.05,118}$	1.66

INDEPENDENT VARIABLES	COEFFICIENTS	STANDARD ERROR	| t STATISTIC |
Patch Area	-0.8	0.14	5.93*
Patch Interior	1.34	0.53	2.55*
Any Road Distance	18.37	8.6	2.14*
Main Road Distance	1.38	1.63	0.85
ANSI Distance	-2.59	0.7	3.70*
Wetland Distance	2.2	0.9	2.46*

4.6.4 Mean Conservatism Coefficient (MCC)

Although the multiple regression between MCC and the independent landscape variables was significant ($F_{0.05(1),6,118} = 2.18$, $F_{obs} = 2.29$), it did not have a strong relationship with the independent landscape variables ($r^2 = 0.10$). Mean conservatism was also plotted against log of patch area (Figure 26). Again, the regression was significant ($F_{0.05(1),1,128} = 3.92$, $F_{obs} = 4.83$) but there was not a strong relationship between mean conservatism coefficient and patch area ($r^2 = 0.1$). In an ANOVA (Table 8), mean conservatism per patch was not significantly different between woodland patch sizes. Instead, as is evident from Figure 26, some of the smallest patches (< 4ha) have mean conservatism scores close or equal to many of the larger patches. Therefore, small patches may have lower species richness (*i.e.* number of native plants) but relatively higher conservatism scores, suggesting that smaller patches are supporting populations with moderately high conservatism scores that are being retained even though total species richness is low relative to other sites. This means that very small patches must be examined individually for community characteristics and conservative species. Bowles (1997) has suggested that past management history could account for the high mean conservatism values.



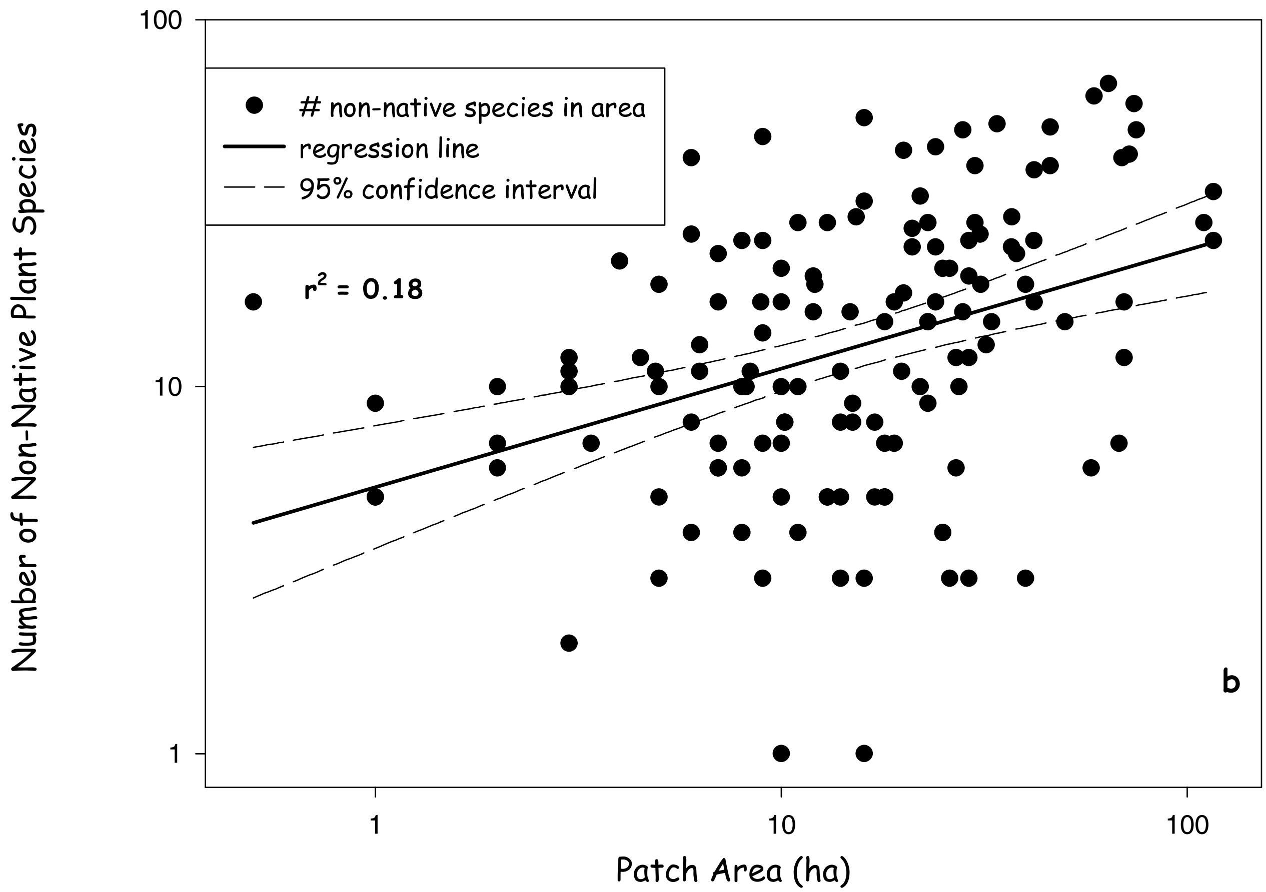


Figure 25. Regression of a) native and b) non-native plant species richness against patch area (ha) surveyed in MNHS and LSWS.

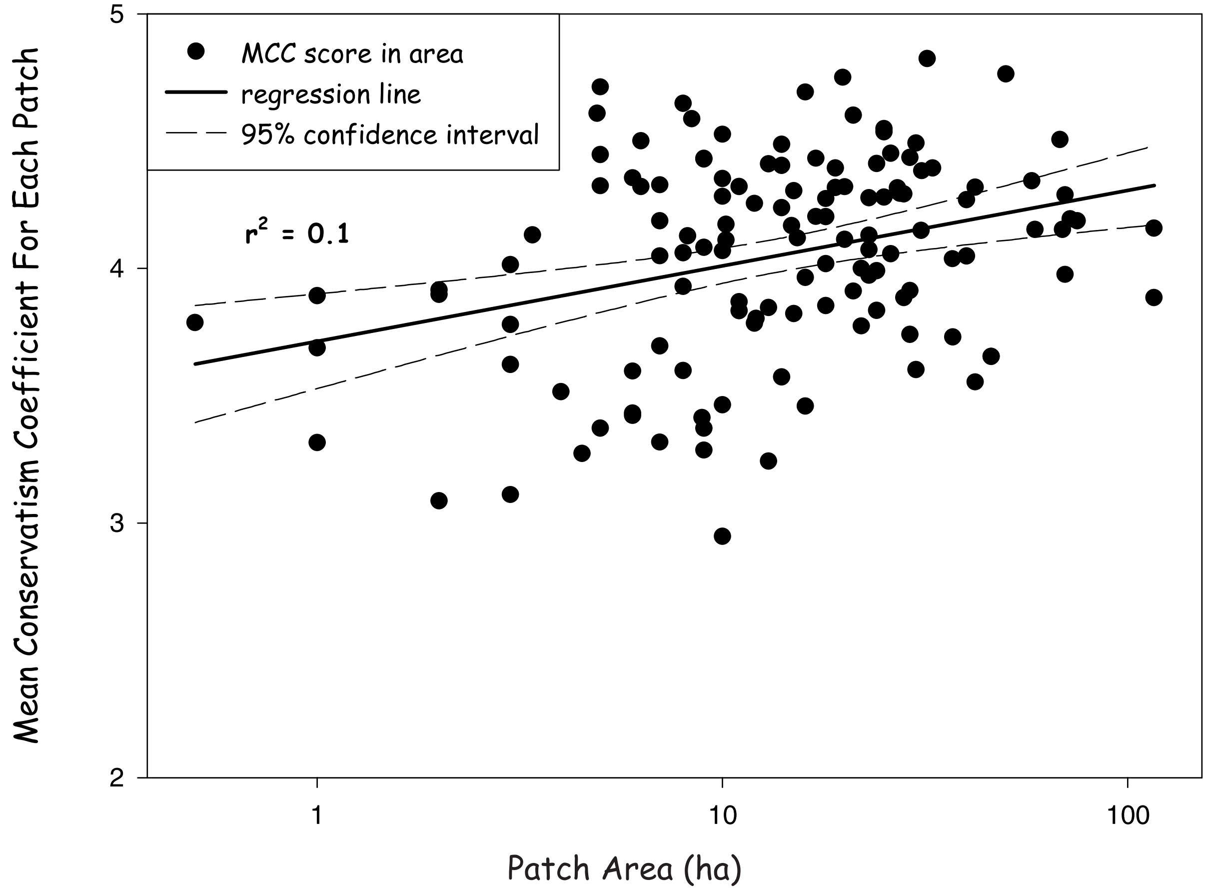


Figure 26. Regression of mean conservatism coefficient against patch area (ha) for surveyed patches in MNHS and LSWS.

4.6.5 Basal Area

There was no significant relationship between basal area and any of the landscape parameters (*i.e.* $F_{obs} < F_{crit}$). Given the highly cultural landscape of Middlesex County, it is not unexpected that basal area would be more influenced by private landowner initiatives (*i.e.* tree cutting) than by the surrounding landscape.

4.7 SUMMARY OF KEY RESULTS AND RECOMMENDATIONS

Size of Woodland Patches
Over 50% of the woodland patches in Middlesex County are less than 4 ha in area and less than 10% are greater than 40 ha. By protecting only the larger patches, there would be a significant loss of a large number of woodlands.

Distribution of Woodland Patches
Ideally, woodland cover should be maintained on all representative physiography and soil types to maintain diversity. A relatively small proportion of Undrumlinized Till Plains and Clay Plains are covered in woodlands, given that these areas are relatively flat and conducive to mechanized agriculture. Remnant woodlands in these areas tend to be smaller and of uniform geometric shape occurring as isolated fragments along roads and lot boundaries.

Kame Moraines, Peat and Muck, Beveled Till Plains and Beaches or Shore Cliffs are uncommon physiographic types, yet a large proportion of these areas are covered in woodlands. These areas are characterized by poor drainage and undulating topography which are not conducive to highly mechanized agricultural practices or to agricultural crops with shallow root systems. Remnant woodlands tend to be long and continuous, but irregularly shaped.

County Forest Cover
Forest cover in Middlesex County is approximately 12.3%. In a joint paper by Environment Canada, the Ontario Ministry of Natural Resources and the Ontario Ministry of the Environment (1998) that provides guidelines for habitat rehabilitation in Ontario, it is recommended that the percent woodland cover in a watershed should exceed 30% in order to support most forest breeding bird species. The Ontario Ministry of Natural Resources (2000c) similarly recommends that woodland cover be retained above a 30% threshold to maintain area-sensitive woodland breeding species and to protect water quality, air, soil, *etc.*

American Forests (2001) recommend that 40% woodland cover should be maintained to benefit air quality since leaf surfaces act as ozone reaction sites. Therefore, retention of forest cover can play a significant role in mitigating episodes of poor air quality usually associated with high ozone episodes during the summer months. McPherson *et al.* (1997) and Scott *et al.* (1998) have shown that urban forests play a significant role in reducing air pollution in an urban environment. Weathers *et al.* (2001) found that forest edges function as significant traps for air-borne nutrients and pollutants from adjoining agricultural or urban landscapes, further justifying the retention of small woodlands with respect to atmospheric effects.

<u>Change in Forest Composition</u>

The relative proportion of Silver and Red Maple, ash, aspen, hickory and Tamarack have all increased since the 1950 and 1960s, while White Elm, Black Cherry, oak and American Beech have decreased. Possible reasons include the value of timber species, the successional nature of tree species, pest outbreaks, changes in recreation and grazing activities as well as large scale effects such as climate change and distribution on physiographic types. Successional age was generally young, with over 60% of the communities within the surveyed woodland patches described as young or pioneer. This suggests that the forests of Middlesex County are mainly in a disturbed successional condition, still recovering from human disturbance activities. Mature community types are rare (less than 60% of the communities within the surveyed woodland patches) in Middlesex County.

<u>Basal Area</u>

Approximately 45% of the upland forests in Middlesex County fall outside the provincial post logging basal area standard of 15 m^2 / ha (OMNR 2000b) and the average tree diameter is small. There is an over abundance of small trees but there are too few large trees, which means that most of the trees in the remnant woodlands are not growing at their optimal rate.

Selective cutting for size (*i.e.* diameter limit cutting), which does not restrict the number of trees cut, often results in a forest that is not harvestable for several decades. A better harvesting technique should consider the residual (*i.e.* post logging) basal area and selectively cut for both diversity in size and species. Under this type of harvesting, a certified marker would identify individual trees to be retained prior to harvesting. The composition and amount of tree harvesting can be amended to maintain or enhance forest diversity.

<u>Disturbance</u>

The most prevalent and intense types of natural disturbance include disease, canopy gaps and wildlife browse while fire and flood events were the least prevalent. The most prevalent and intense types of human disturbance include trails, non-native plants and noise while sugar bush operations, earth movement and recreation activities were the least prevalent. The effects of human disturbance were much more variable than natural disturbance, demonstrating the difficulty in classifying remnant forest patches on the landscape, since different human disturbances will have different effects on the vegetation.

<u>Species Richness (excludes sedges)</u>

Approximately 40% of all species recorded for Middlesex County were found in the MNHS and LSWS. Of these, 14% of the total number of native species in MNHS and LSWS were recorded only once out of the 153 patches and all physiographic types (with the exception of Kame Moraines) contained at least one species that was not found in any other physiographic type. This result suggests that all individual patches and physiographic types are important in maintaining plant species diversity.

When weediness scores were broken down into physiographic type, Peat Muck, Beach and Spillways had higher patch weediness scores per area sampled than other physiographic types. Since these physiographic types are often associated with surficial flow, the dispersal rates of non-native seed sources may be higher in these areas.

Recognizing that the MNHS and LSWS focused on typical, remnant woodland patches on the landscape, the mean and the distribution of conservatism coefficients were lower (*i.e.* fewer conservative species) for these studies than what was found for all of Middlesex County where pristine and special areas (such as ANSIs) would be represented in the overall County list.

5. Identification of Significant Woodland Patches

This chapter uses landscape principals to develop criteria for the significance of woodlands in Middlesex County.

5.1 RATIONALE FOR LANDSCAPE CRITERIA

As defined by the Provincial Policy Statement (Ontario Ministry of Municipal Affairs 1997), significant woodlands are those that are:
"...ecologically important in terms of features, functions, representation or amount, and contributing to the quality and diversity of an identifiable geographic area or natural heritage system. Criteria for determining significance may be recommended by the Province, but municipal approaches that achieve the same objective may also be used".

The Natural Heritage Reference Manual (OMNR 1999) further identifies the following evaluation factors for determining significance:

- woodland size
- woodland shape and proximity to other woodlands or to other habitat types
- linkages
- woodland diversity
- uncommon characteristics (*i.e.* composition, cover type, quality, age, age structure, *etc.*)
- economic and social values

Some of these factors would require detailed vegetation surveys. Since this is not possible given the large number of woodland patches in Middlesex County, a landscape ecosystem approach was used instead. The advantage in applying a landscape approach for recognizing woodlands, as opposed to a site-specific approach, is that it can be applied at the County scale and does not require detailed vegetation surveys.

The selection of criteria for determining significant woodlands was based on three key concepts of natural heritage planning identified by Riley and Mohr (1994):

1. protection of core areas;
2. restoration of corridors associated with watercourses; and
3. replacement of connecting linkages on the landscape.

and on the following two principals:

1. The criteria should identify a measure of the contribution of the woodland to its landscape ecosystem function at a county scale.
2. The criteria must be measurable and based on a data set that represents all of the woodlands in Middlesex County (*e.g.* intrinsic variables derived from comprehensive field inventories are not available for all woodlands).

Incorporating the three key concepts of Riley and Mohr (1994), as well as results from the scientific literature, input from the steering committee and the significant correlations from regressional analysis between the independent landscape parameters and the dependent site specific forest health indicators collected in the field, six landscape criteria (Table 10) were developed to identify candidate woodland patches in Middlesex County. A woodland patch only had to meet one of the criteria to be recommended as a candidate for significance in the context of the Provincial Policy Statement 2.3 for Middlesex County.

Many of the criteria and associated thresholds are similar to the rational and methodology independently derived for determining significant woodlands in the Regional Municipality of Halton (Gartner Lee Limited 2002).

Table 10. List of the six landscape criteria used to evaluate woodland patches in Middlesex County. All patches are pre-screened using any or all of these landscape criteria. The entire patch is identified if it meets one or more criteria.

LANDSCAPE CONNECTIVITY

1. Any woodland patch where 50% of the area is within 750 m of a recognized Natural Heritage Feature.*

2a. Any woodland patch greater than 10 ha in area.

2b. Any woodland patch less than 10 ha that contains forest interior (defined as treed habitat more than 100 m from the patch edge).

3. Any woodland patch within 100 m of a woodland patch greater than or equal to 10 ha.

4. Any woodland patch in a recognized corridor.**

HYDROLOGY

5a. Any woodland patch containing a watercourse.

5b. Any woodland patch within 50 m on either side of a watercourse but not containing a watercourse.

6. Any woodland patch on porous soils that may have sensitive groundwater recharge / discharge resources.

* Natural Heritage Features recognized (*i.e.* features listed or mapped) in the County Official Plan or City of London Official Plan.
** Recognized corridor includes Big Picture Corridor, Ausable River Corridor and Thames River Valley Corridor.

5.2 DEVELOPMENT OF EACH LANDSCAPE CRITERION

An additional 1 km buffer was placed around the boundary of geographic Middlesex to ensure that the entire woodland patch, and not just the portion within Middlesex County, was evaluated. To generate maps of woodlands that fulfilled each criterion, spatial analysis methods were applied to the updated digital woodland patch layer (excluding all woodland patches 0.5 ha or less). As well, six maps by criterion, plus a map of all woodland patches that met at least one of the criteria (to identify candidate woodlands of county significance), were generated for committee and public review.

5.2.1 Criterion 1: Any woodland patch where 50% of the area is within 750 m of a recognized Natural Heritage Feature ("core area").

Objective

The objective of Criterion 1 is to ensure connectivity between the recognized and protected core areas in Middlesex County and other natural heritage features that support them. This criterion strongly complements Policy 2.3.3 of the Provincial Policy Statement (OMNR 1999). Moreover, a variety of ecological models, such as metapopulation, percolation theory and island biogeography, demonstrate that an absence of surrounding vegetation for core areas can jeopardize the long-term stability of these core areas.

Rationale and Identification of Woodlands

When the number of native plant species per patch for the MNHS and the LSWS was tested against distance from an ANSI , a significant negative relationship was found. That is, the shorter the distance between the woodland feature and the ANSI, the greater the number of native plant species in the woodland. Thus, ANSIs are supporting neighbouring sites, making them more significant. As well, woodland patches closer to ANSIs have fewer non-native species (Table 7) and fewer highly aggressive species (Table 9) than woodland patches farther from ANSIs. Woodland patches closer to wetlands had greater numbers of native species as well as more aggressive (more negative weediness scores) non-native species than woodland patches farther from wetlands. Given that water aids species dispersal, it is understandable that seeds from both native and non-native plants are likely to be dispersed between wetlands and nearby woodlands since many wetlands are associated with surficial flow.

According to the Southern Ontario Wetland Manual (OMNR 1994), "wetland complexes are commonly related in a functional way, that is, as a group they tend to have similar or complementary biological, social and / or hydrological functions. Much of the wildlife in the area of a complex is also dependent to varying degrees upon the presence of the entire complex of wetlands, with each wetland unit contributing to the whole." Since 750 m is the maximum distance for complexing wetlands (OMNR 1994) and most recognized natural features contain wetland components, 750 meters was selected as the maximum distance between recognized natural heritage features and a woodland feature. Therefore, any wetland unit within 750 m of another may be considered to be part of a complex whether or not a direct hydrological connection exists (OMNR 1994). As well, 750 m is the distance at which linkages between the recognized natural heritage features and other woodland patches start to appear on the Middlesex landscape. Linkages are important for dispersal of plants and animals. For example, Wilcove (1988) has shown that even widespread forest-associated breeding birds may be absent in forests as large as 20 hectares if they are isolated. It was decided that 50 percent of a woodland patch must fall within750 m of a recognized natural heritage feature to ensure that the woodland patch was functioning as part of the natural framework for that feature.

Methodology

Appendix 9 is a list of all recognized natural heritage features in Middlesex County. A recognized natural heritage feature includes Provincially Significant Wetlands (PSWs), Locally Significant Wetlands (LSWs), Areas of Natural and Scientific Interest (ANSIs) and Environmentally Significant Areas (ESAs). Boundaries of PSWs and LSWs were defined and mapped by the 1983 / 1984 OMNR wetland evaluations. Two wetland boundaries were updated by the OMNR (Campbellville Swamp in 1999 and Arva Moraine Wetland in 1998). Boundaries of ANSIs were defined by Hilts and Cook (1982) and summarized by Jalava (1996) for Middlesex County. Boundaries of ESAs, originally defined by Hilts and Cook (1982), were updated by the City of London in 2002. The most recent updated boundaries were used in this analysis.

Using the buffer tool in ArcInfo, a 750 m buffer was placed around the outside perimeter of each recognized natural heritage feature. Any neighbouring woodland patch with 50% of its area within this buffer limit was captured for this criterion.

5.2.2 Criterion 2: Any woodland patch greater than 10 ha in area or any woodland patch less than 10 hectares that contains forest interior.

Objective

The objective of Criterion 2 is to identify the minimum sized woodland patches that serve a variety of ecological functions.

Rationale and Identification of Woodlands

Based on work by Levenson (1981), Riley and Mohr (1994) recommend that woodlands dominated by mesic beech-maple forests should be protected if they are at least 4 ha in size. Sugar Maple - Beech forests are the dominant forest type in Middlesex County. The OMNR Natural Heritage Reference Manual (1999) also recommends that the size of woodland patches considered to be significant within the planning area is a function of the percentage of woodland cover within that area. Within Middlesex County, the percentage of woodland cover is approximately 12%. Therefore, all woodland patches 4 hectares or greater in size would be considered to be significant (OMNR 1999). Indeed, this study found high mean conservatism scores for small woodland patches (Figure 29). Some of the smallest patches (< 4ha) have mean conservatism scores close to or equal to many of the larger patches, suggesting that moderately high conservatism scores are being retained even though total species richness is low relative to other sites. This means that very small patches must be examined individually for community characteristics and conservative species.

However, there appears to be general agreement that forests below ten hectares are unlikely to be productive for many forest-associated wildlife species (*e.g.* Freemark and Collins 1992, Riley and Mohr 1994). The Area of Concern (AOC) guidelines (Environment Canada *et al.* 1998) and the Guidelines for Significant Habitat (OMNR 2000c) also indicate that woodland patches of 10 ha begin to offer functions associated with area-sensitive and disturbance-sensitive wildlife species. For example, area-sensitive breeding birds such as the Hairy Woodpecker (*Picoides villosus*) and White-breasted Nuthatch (*Sitta carolinens*) only begin to be supported by forest units as large as ten hectares.

It is generally well established that as forest area increases, so does the diversity of forest-associated breeding bird species. In southern Ontario, Freemark and Collins (1992) showed that the presence of all bird species increased as a function of forest size. Models of island biogeography also predict that plant species will increase with patch size (McAurthur and Wilson 1967). These models, which have been applied to studies of fragmented forest patches, predict that species richness will increase with patch size up to the regional species diversity. The number of native plant species (Table 6), non-native plant species (Table 7) and the sum of weediness scores (Table 9) had significant positive relationships to patch area. Therefore, the larger the woodland patch area, the greater the number of plant species (both native and non-native) but the less aggressive (*i.e.* more positive weediness score) the non-native plant species.

There is general agreement that forests between 10 ha and 50 ha in area have elevated functions for wildlife. For example, In a study of the Farewell Creek watershed (Henshaw and Leadbeater 1999), forests 10 to 25 ha in size were supported by the data as an appropriate break in the designation of secondary core natural areas, while a minimum 25 ha threshold was designated as an appropriate break for core natural areas. The AOC guidelines further suggest that habitat suitability for populations of area-sensitive species increases as patch sizes increase between 10 and 30 ha. In Middlesex County, most of the quality indicators do not express themselves consistently until woodland patches are at least 10 ha in size. Figure 23 shows that 10 ha is the approximate size at which woodland patches had at least 2 ha of interior habitat. Given that Middlesex County has approximately 12% forest cover remaining, 10 ha was selected as an appropriate critical size to capture a variety of forest functions.

Recognizing the numerous functions attributed to woodlands with forest interior (*e.g.* reduction in edge effects such as sun scald, windfall and invasive species as well as habitat for many area-sensitive bird species), all woodland patches that do not meet the 10 ha woodland size but that do have forest interior are also recognized in this criterion. This is supported by Riley and Mohr (1994), who suggest that potential for habitat for disturbance sensitive species can occur in woodlands that are 4 ha, as long as they have a minimum diameter of 100 m (*ie.* contain some interior forest).

Methodology

Using the inquiry tool in ArcInfo, the area of woodland patches was determined. Using the buffer tool in ArcInfo, a 100 m buffer was placed around the inside perimeter of woodland patches less than or equal to 10 ha (Figure 6). The remaining amount of area not in the 100 m buffer (called interior) was summed for each woodland patch. Some irregularly shaped woodlands had more than one section of interior (*e.g.* not continuous but fragmented). All woodland patches greater than 10 ha as well as woodland patches less than or equal to 10 ha in size with greater than a sum of 0.5 ha of forest interior were designated for this criterion.

5.2.3 Criterion 3: Any woodland patch within 100 m of a woodland patch greater than or equal to 10 hectares.

Objective

The objective of Criterion 3 is to identify woodland patches that are more significant and healthy because they are near (and influenced by) larger woodland patches.

Rationale and Identification of Woodlands

Linkages are important for both animal and plant dispersal. Bowles (1997) found that species richness was higher for small patches closely linked to larger patches than similarly sized patches not linked to larger patches. However, the identification of landscape connectivity is an evolving science. Recognizing the non-random pattern of remnant woodland patches on the County landscape and that most woodlands are relatively equi-distant from each other, it is not surprising that there was not enough variability in this measurement to determine relationships between nearest neighbour and woodland patch indicators of health. Instead, 100 meters was selected as the maximum distance between woodland patches since this is the distance at which linkages between woodland patches start to appear (Figure 24). One hundred metres is also the distance that most seeds dispersed by wind can travel (Nathan *et al.* 2002). Fifty percent was selected as the minimum amount of woodland patch that must be within this distance to ensure that the majority of the patch will be influenced by its neighbour.

Methodology
Using the buffer tool in ArcInfo, a 100 m buffer was placed around the outside perimeter of each woodland greater or equal to 10 ha. Any woodland patch found within this buffer limit (in whole or in part) was designated for this criterion.

5.2.4 Criterion 4: Any woodland patch within a Carolinian Canada Big Picture corridor, the Ausable River corridor and the corridor along the North Branch of the Thames River. Only woodlands that do not contain a watercourse or are not within 50 m of a watercourse are identified in this criterion.

Objective
Networks of natural areas are considered the best way to maintain ecological diversity and health in an agricultural landscape (Riley and Mohr 1994). The woodlands identified in these corridors provide broader linkage opportunities between regions.

Rationale and Identification of Woodlands
Carolinian Canada Big Picture corridors have been identified for most of Middlesex County (Bigger Picture Phase 2, 2003). Two additional corridors were included in this criterion: the Ausable River corridor, which was identified in the 1995 Ausable Bayfield Conservation Authority Watershed Management Strategy (Snell and Cecile Environmental Research 1995), and the corridor along the North Branch of the Thames River, which was recognized in the Life Science Inventory of the Thames River between St. Marys and Fanshawe Lake (Stephenson 1991). These are the largest natural heritage corridors in the county and, therefore, are of prime importance to the ecosystem and to wildlife. The three corridors were identified by the existing landscape pattern, incorporating and enlarging the major natural core areas and linking them along major water bodies and major upland woodland corridors. Existing natural areas and natural linkages were used as much as possible to keep intrusion into agricultural land at a minimum.

Methodology
Any woodland patch found within these corridor boundaries (in whole or in part) was designated for this criterion.

5.2.5 Criterion 5: Any woodland patch containing or within 50 m of a watercourse.

Objective
The objective of Criterion 5 is to protect the features and functions of watercourses. The riparian functions that woodlands perform include erosion control and stability, thermoregulation and humidity control, nutrient flow and maintenance of stream flow.

Rationale and Identification of Woodlands
A comparison of flow data (from September 1986, January 1993, May 1996 and April 2001) from the South Saugeen River near Neustadt and the Teeswater River used in Environment Canada's 2001 Temperate Wetland Restoration Course, illustrate the profound difference in hydrographs produced by a forested versus an unforested watershed. The relatively unforested South Saugeen graphs show a flash point following a rain event and an equally severe drop to background levels. The forested Teeswater River, however, rises slowly following a rain event, sustains slightly higher flows for a longer period and then gently subsides. In addition, water quality at the confluence of Teeswater and Saugeen Rivers is dramatically different, with clear water in the Teeswater River downstream of Greenock Swamp and muddy brown water in the Saugeen River.

Woodlands or natural areas situated along large rivers provide habitat, bank stability and flood absorption functions, while woodlands or natural areas along smaller streams have more impact on water quality. To determine how far from a river a woodland had to be to have an impact on it, several literature sources were reviewed. OMNR (2000a) found that buffer widths of 30 m to 90 m are needed for adequate removal of smaller particles found in urban runoff. Castelle *et al.* (1994) found that buffers less than 10 m provide little protection of aquatic resources. Griffiths (2001) concluded that if 26% of the land within 100 m of streams was in a natural state, the water quality in the streams would be unimpaired. Other references (OMNR 1987, Johnson and Ryba 1992, O'Laughlin and Belt 1995) recommend a horizontal distance of at least one and a half times the height to which the trees in the adjacent woodland could be expected to grow. In Middlesex County, the potential height of the maples, elm, walnut, oak and pine varies from 25 m to 35 m. This translates into a threshold of approximately 50 m.

Recent investigations have documented that energy flow from the watercourse to the woodland could occur at least 100 m away from a watercourse. For example, Semeniuk (2001) demonstrated that the predation of salmon by grizzly bears and subsequent removal to upland woodlands may account for up to half of the nitrogen fixed by the trees. The possibility that birds and mammals found in Middlesex County, such as osprey, heron, mink and racoon, may be contributing to the health of the woodlands in a similar way gives additional credence to the interaction of watercourses and their adjoining habitats.

Large blocky buffers provide optimal wildlife habitat while dense, narrow buffers may be effective at reducing sediment delivery at critical points (Lowrance *et al.* 2002, Welsh 1991). A 50 m wide buffer was chosen for this study as a reasonable minimal width to provide good buffering functions (*i.e.* moderate temperature and buffer erosion, sedimentation and runoff) and wildlife habitat or corridor functions for edge species (Johnson and Ryba 1992, Beschta *et al.* 1987 and OMNR 2000c).

Methodology
Watercourses were identified from 1:10,000 OBM maps and are based on a centre line (Appendix 6). The ABCA, SCRCA and UTRCA ground truthed this data at 1:5,000. Watercourses can have either permanent and intermittant flow. Both the ABCA and UTRCA removed closed (subsurface groundwater) drains.

Using the buffer tool in ArcInfo, a 50 m buffer was placed on either side of the centre line used to define watercourses. Thus, riparian buffers adjacent to larger streams were much narrower than 50 m, while buffers adjacent to smaller streams were approximately 50 m, owing to the width of the stream. The increased amount of buffer in smaller streams is justified when hydrological functions of woodlands is considered. Hydrological function is related to the area of the woodland divided by the area of the subcatchment upstream of the woodland and the stream order into which it drains. Therefore, woodlands have decreasing significance with respect to management of surface flow and groundwater infiltration with an increase in upstream area and stream order.

Any woodland patch intersected by the watercourse centre line (in whole or in part) or found within the 50 m limit on either side of the watercourse centre line, was designated for this criterion.

5.2.6 Criterion 6: Any woodland patch on porous soils that may have sensitive groundwater recharge or discharge resources.

Objective
The objective of Criterion 6 is to ensure the integrity of the groundwater resource.

Rationale and Identification of Woodlands
All woodlands that intersect areas of groundwater seepage will be designated since the loss of these woodlands may result in a degradation of both groundwater quality and quantity. By preserving woodlands on porous soils, areas with high percolation and recharge potential are protected and land uses that could potentially pollute groundwater supply are avoided.

Until detailed groundwater studies and comprehensive hydrogeological mapping are completed (currently underway), all woodlands on porous soils will be recognized as potential zones of groundwater recharge / discharge. This criteria will be modified when the groundwater studies for the County have been completed.

Methodology
Digital soil information for Middlesex County was provided by OMFRA (1985). Porous soils were defined as very fine sandy loam, sandy loam, fine sandy loam and fine sand. Any woodland patch found within these soil types (in whole or in part) was designated for this criterion.

5.3 IDENTIFICATION OF SIGNIFICANT WOODLANDS

Significant woodlands are those woodland patches that meet at least one criteria. Figure 27 illustrates the woodlands that fulfilled any one of the criteria and are recommended for designation as significant in the context of the Provincial Policy Statement 2.3 for Middlesex County (does not include First Nations or City of London). Table 11 shows the percent of woodland patches that meet a certain number of criteria. Based on the six criteria, 74% of woodland patches in Middlesex County perform significant functions on the Middlesex landscape. Since the woodlands have been designated using a methodology that compares woodland characteristics within the context of the County of Middlesex as a whole, it is important to recognize that the features of an individual woodland cannot be evaluated without returning to the County context.

Intrinsic characteristics, such as habitat of endangered and threatened species, are not included in the methodology since the occurrence of species of conservation concern is incomplete. However, GIS queries were constructed to identify woodland patches that have been previously identified as habitat of endangered and threatened species but not identified as significant woodlands based on the six landscape criteria. Only two woodland patches that contain significant habitat of endangered and threatened species were not captured by this study.

Table 11. The percent of woodland patches in geographic Middlesex County that meet a certain number of criteria (including all woodland patches that fall partially within County boundary, City of London and First Nations).

Number of Landscape Criteria	Percent in Geographic Middlesex
0	26.11%
1	28.53%
2	21.77%
3	14.21%
4	6.85%
5	2.51%
6	0.02%

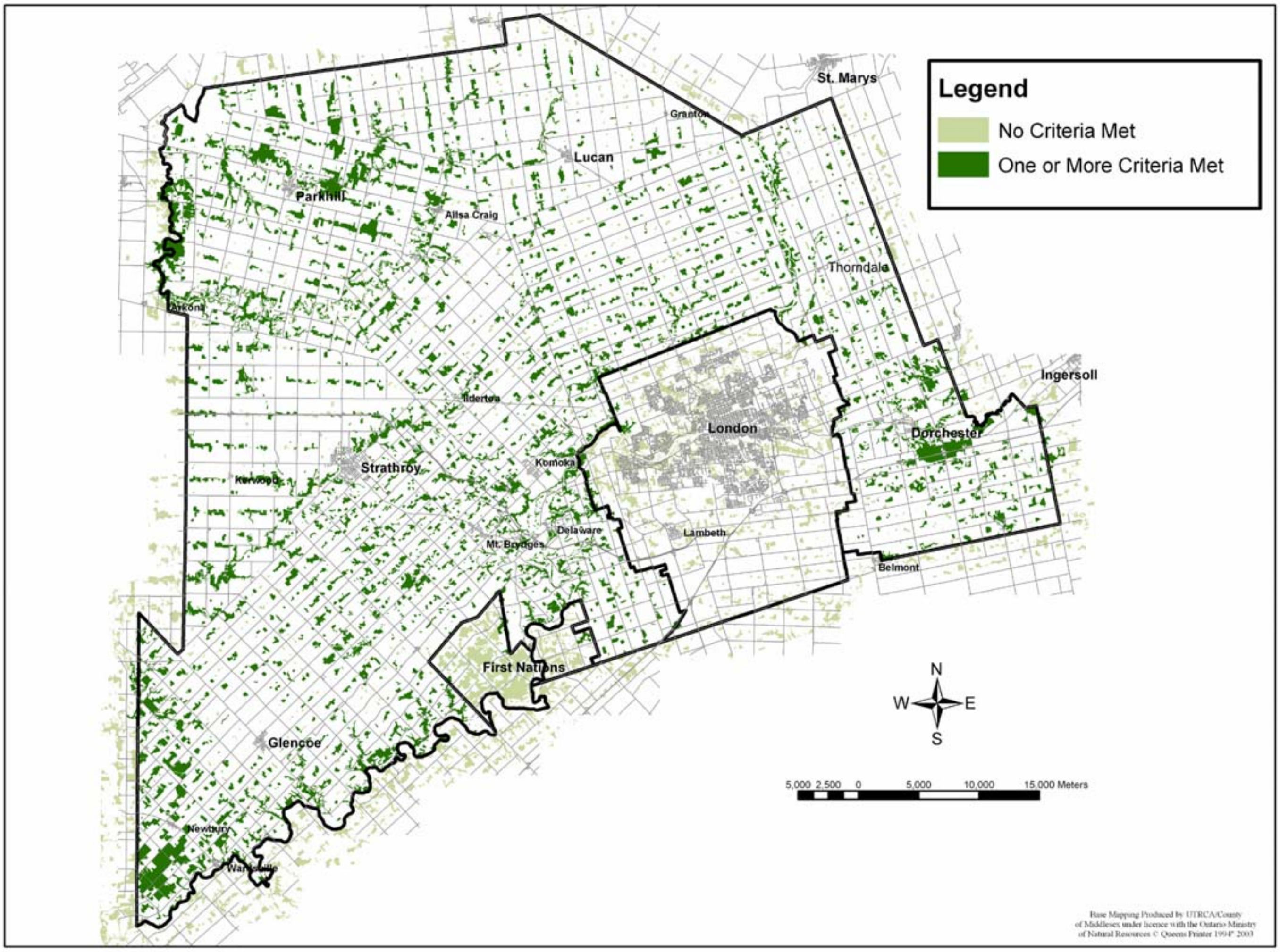


Figure 27. Woodland patches in Middlesex County that meet one or more landscape criteria.

5.4 SUMMARY OF KEY POINTS AND RECOMMENDATIONS

The recommendations are:

1. That the six criteria be approved as the basis for designation of significant woodland patches in Middlesex County.

2. That all woodland patches that fulfilled any one of the six criteria are recognized as significant in Middlesex County.

3. That 30 % forest cover is the recommended minimum to maintain healthy ecosystems (Riley and Mohr 1994, Environment Canada *et al.* 1998, Ontario Ministry of Natural Resources 2000c) and that Middlesex County's forest cover of approximately 12% is far below the recommended target of 30%. Therefore, all woodland patches in the county, even those that do not meet any one of the six criteria, are recognized as important to the entire system.

4. That when reviewing the features of an individual woodland, they must be evaluated within the context of the County and not on a woodland by woodland basis. The Terms of Reference for Development Assessment Reports should include confirmation of the functions for which the candidate significant woodland was designated.

5. That the ELC be endorsed as the standard for vegetation classification in Middlesex County and that a strategy for completing the classification of woodland patches to at least the Community Series level be adopted.

6. That the County develop a protocol for the addition or removal of a woodland to or from the candidate significant woodlands layer as a result of any discrepancies or ambiguities created by unavoidable uncertainties in the GIS methodology used to create these candidates.

6. Implementation

The MNHS focuses on the scientific methodology to identify woodland patches that are of County significance. The Landscape Criteria allow for the mapping of patches that are considered to be significant and that should be maintained through implementation. In addition to identifying areas for protection, the landscape map can also be used to identify areas where restoration efforts and efforts to link existing patches and increase forest interior should be concentrated.

There are numerous options for implementing the findings of the MNHS. Through the study, the following five main categories of options have been discussed:

6.1 IMPLEMENTATION TOOLS

Regulatory Measures

Measures to control an individuals freedom to act for the benefit of the individual, the community or the broader public interest. Two regulatory measures that are applicable in this case are:

i) the regulation of land use through official plan policy and zoning by-law regulation under the jurisdiction of the Planning Act

ii) the regulation of tree cutting under the County Tree Cutting By-Law made pursuant to the Trees Act

Stewardship

Tools for landowners and the community to undertake measures which sustain and improve resources.

Education

Creating a broad awareness of the importance of the resource and actions that can be taken to maintain and restore the resource. Education and stewardship are closely linked.

Incentives

Measures that reward good management practices. The incentive can be financial or simply recognition.

Acquisition

Outright purchase of land or easements as a means of obtaining management control.

A comprehensive program to achieve the goals identified for the natural heritage of Middlesex County could involve elements of each of these measures and it may involve strategies which go beyond the ones that are listed. The development of implementation programs, the delivery of these programs and the regular evaluation of the programs against their identified goals is a responsibility that rests with all of the partners that were involved in the project. The MNHS study does not lay out a comprehensive implementation plan but rather, provides a standard information baseline and a method for identifying woodlands of County significance which can be used as a starting point for individuals to manage their woodlands and for organizations to develop programs.

6.2 LAND USE PLANNING

With the County being the proponent of the MNHS and the expectation that the study would provide information to support the five year update to the County Official Plan, the MNHS did give significant consideration to implementation of the study through land use planning. The following land use planning related implementation recommendations were presented to Middlesex County Council by the Steering Committee:

- It is recommended that the County place all patches that meet one or more of the landscape criteria in a “natural heritage” designation that is accompanied by policies designed to maintain existing areas.
- It is recommended that the “natural heritage” policies specifically allow uses such as maple syrup production, passive trails and forestry following good forest management practices, to continue.
- It is recommended that stewardship policies encouraging the maintenance of all woodland patches be incorporated into the official plan.
- It is recommended that the policy framework of the official plan take a landscape protection approach to natural heritage verses a patch protection approach. The approach advocated would result in the maintenance of all natural heritage patches that meet one criteria and the emphasis would be on protecting the system rather than assessing the impact of the loss of parts of the system.

In addition to making the foregoing recommendations, a modified policy framework was provided to the County. The policy framework was based on the existing Middlesex County Official Plan policy and included revisions which would implement the recommendations noted.

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